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OPTIMALLY REORGANIZING NAVY SHORE INFRASTRUCTURE

by

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The end of the cold war has allowed the United States to significantly reduce defense spending. Spending has been reduced for both the force structure (i.e., equipment and manpower) and the military support base (i.e., infrastructure), but infrastructure reductions continue to lag force structure reductions. The United States Navy's recent initiatives to reduce its shore infrastructure costs include "regionalization," "outsourcing," and "homebasing." While regionalization and outsourcing decrease the number of jobs needed on a shore installation, homebasing generally increases the number of available personnel. These opposing effects require careful implementation. This thesis develops the Regionalization and Outsourcing Optimization Model (ROOM), an integer linear program that identifies an optimal combination of regionalization and outsourcing options for a Navy shore installation with personnel altered by homebasing. A ROOM test case uses actual data from the Pearl Harbor Naval Installation with proposed homebasing and regionalization and outsourcing options for 109 "functions," or shore installation activities. Disregarding homebasing and its opposing effects, regionalization is the lowest cost option for 106 of these functions. ROOM's optimal solution, however, recommends regionalizing only 21 functions, outsourcing 14, and leaving 74 unchanged. This solution yields a first-year savings of $9.5 million.

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OPTIMALLY REORGANIZING NAVY SHORE INFRASTRUCTURE

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ABSTRACT

The end of the cold war has allowed the United States to significantly reduce defense spending. Spending has been reduced for both the force structure (i.e., equipment and manpower) and the military support base (i.e., infrastructure), but infrastructure reductions continue to lag force structure reductions. The United States Navy's recent initiatives to reduce its shore infrastructure costs include "regionalization," "outsourcing," and "homebasing." While regionalization and outsourcing decrease the number of jobs needed on a shore installation, homebasing generally increases the number of available personnel. These opposing effects require careful implementation. This thesis develops the Regionalization and Outsourcing Optimization Model (ROOM), an integer linear program that identifies an optimal combination of regionalization and outsourcing options for a Navy shore installation with personnel altered by homebasing. A ROOM test case uses actual data from the Pearl Harbor Naval Installation with proposed homebasing and regionalization and outsourcing options for 109 "functions," or shore installation activities. Disregarding homebasing and its opposing effects, regionalization is the lowest cost option for 106 of these functions. ROOM's optimal solution, however, recommends regionalizing only 21 functions, outsourcing 14, and leaving 74 unchanged. This solution yields a first-year savings of $9.5 million.

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EXECUTIVE SUMMARY

The end of the cold war has allowed the United States to significantly reduce defense spending. Initial reductions were in forces (i.e., equipment and manpower) because budget cuts in these areas were politically feasible and provided immediate savings. Because fewer forces require less support structure, reductions in the military support base, or infrastructure, followed. To date, infrastructure reductions lag force reductions by approximately nine percent. The United States Navy is now actively reducing its shore infrastructure; "regionalization," "outsourcing," and "homebasing" are just a few of the Navy's current initiatives to reduce shore infrastructure costs. While regionalization and outsourcing decrease the number of jobs needed on a shore installation, homebasing generally increases the number of personnel available to fill jobs. These opposing effects require careful implementation. In the past, no method of examining the combined effects of these initiatives existed.

This thesis develops the Regionalization and Outsourcing Optimization Model (ROOM), an integer linear program that identifies the optimal combination of regionalization and outsourcing options for a Navy shore installation. ROOM minimizes cost by selecting the best combination of regionalization and outsourcing options that can be supported by available personnel after making homebasing adjustments.

ROOM test cases use actual data from the Pearl Harbor Naval Installation. Regionalization and outsourcing options are considered for 109 "functions," or shore installation activities. Disregarding homebasing and the combined effects of the options, the least cost option is to: Regionalize 106 of the functions; outsource none; and keep three the same. ROOM's optimal solution, accounting for homebasing and the combined effects, recommends regionalizing only 21 functions and outsourcing 14 functions. ROOM's results provide a first-year savings of $9.5 million. Assuming associated training costs only occur in the first year and savings occur over three years, the net present value of expected savings is $28.8 million.

Some Navy shore installation functions, such as base security and firefighting services, are legislatively constrained from being outsourced. When all functions are made eligible for outsourcing regardless of the legislative constraints, ROOM still does not recommend these functions for outsourcing. However, ROOM does recommend many related functions, such as law enforcement and security training, for outsourcing.

I. INTRODUCTION

The end of the cold war has allowed the United States to significantly reduce defense spending. Initial reductions have been in force structure (i.e., equipment and manpower) since budget cuts in these areas are politically feasible and provide immediate savings. Since fewer forces require less support structure, reductions in the military support base, or infrastructure, followed. To date, infrastructure reductions are significantly less than those of force structure: The Defense Department has reduced the size of the military services by 30 percent, but the cumulative reduction in military infrastructure is only about 21 percent [Defense Base Closure and Realignment Commission, 1995]. The United States Navy is now actively reducing its shore infrastructure; "regionalization," "outsourcing," and "homebasing" are just a few of the Navy's current cost reduction initiatives. In the past, no method of examining the combined effects of these initiatives existed. This thesis develops an integer linear program that identifies the optimal combination of regionalization and outsourcing options for a Navy shore installation. The model minimizes cost while providing all services and accounting for personnel utilization necessitated by the homebasing initiative.

A. BACKGROUND

The Office of the Secretary of Defense (OSD) defines infrastructure as consisting of "those functionally organized activities that furnish resources for the management of defense forces, facilities from which defense forces operate, centrally organized logistics, non-unit training, personnel support, and medical services" [Struble, 1996]. In the United States Navy, infrastructure accounts for approximately 37 percent of the budget: 1998 fiscal year (FY98) infrastructure consumes $25.1 billion of the Navy's $68.5 billion Total Obligation Authority (TOA) (Figure 1) [N464, 1996a].

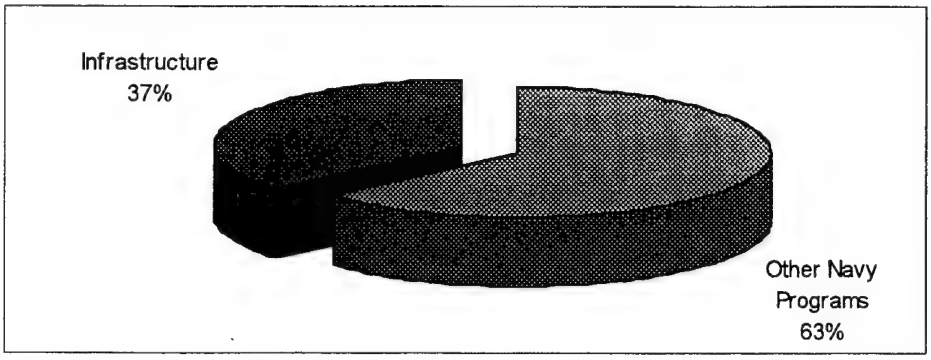

Figure 1. Navy planned infrastructure costs for fiscal year 1998. Infrastructure consumes $25.1 billion of the Navy's $68.5 billion Total Obligation Authority, or approximately 37 percent of the Navy's budget.

Military infrastructure can be streamlined via Base Realignment and Closure (BRAC). BRAC reduces infrastructure by reorganizing some military installations while closing others. After four rounds, a legislative BRAC process concluded in 1995 with the recommendation to close or realign 132 military installations in the United States [Defense Base Closure and Realignment Commission, 1995]. Current projections indicate that BRAC will save $2.4 billion annually, but these savings are less than expected due to unforseen costs and other expenditures that were transferred rather than eliminated [Struble, 1996]. Therefore, all of the armed services are seeking other means of infrastructure cost reduction. In particular, the Navy wants to reduce its shore infrastructure.

B. SHORE INFRASTRUCTURE COST REDUCTION

In 1994, the Shore Installation Management Division (SIMD), or N46, was created under the Deputy Chief of Naval Operations (DCNO) for Logistics. The purpose of SIMD is "to serve as the principal [Navy] point of contact, resources advocate and coordinating authority for the shore installation chain of command in all matters affecting Navy Shore Installation programs to support a high level of fleet operational readiness" [N46, 1997]. N46 heads several new initiatives to reduce shore infrastructure costs falling

into three major areas: (1) regionalization; (2) outsourcing and privatization; and (3) improved operational procedures.

1. Regionalization

A function is any activity performed on a military installation, including those activities identified in the Office of Management and Budget (OMB) Circular A-76, *Performance of Commercial Activities*. Regionalization (Figure 2) is the process of assigning the fiscal and/or administrative responsibility for similar functions in the same region or area to one specific command [Struble, 1996]. Regionalization consolidates installation management functions and eliminates redundancy, thereby reducing shore infrastructure and costs. For example, both the Naval Station and Submarine Base in Pearl Harbor, Hawaii maintain Bachelors' Quarters (BQ's), each with its own administrative branch. Regionalization would reduce infrastructure by combining the responsibility for both BQ's and assigning it to just one of the commands.

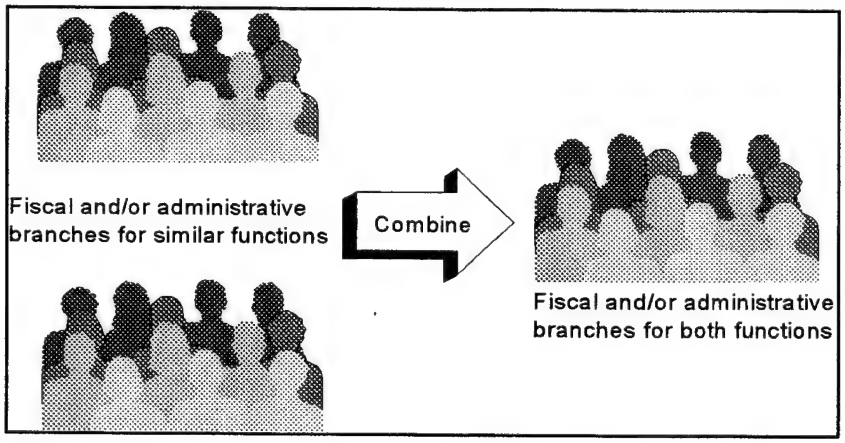

Figure 2. Regionalization is the process of assigning the fiscal and/or administrative responsibility for similar functions in the same region to one command. Note that both facilities and personnel may be reduced through the regionalization process. Bachelors' Quarters (BQ's) within the same area, for example, may combine fiscal and administrative branches through regionalization.

N464, the Plans and Policy Branch of N46, is responsible for gathering the necessary data and making regionalization recommendations for Navy shore installations. N464 first conducted regionalization studies and proposed regionalization alternatives for

the San Diego Naval District [N464, 1996a]. Further regionalization studies are being conducted in Pearl Harbor, Hawaii; Bangor, Washington; and Naval District Washington.

2. Outsourcing and Privatization

Outsourcing and privatization are both concerned with achieving cost savings by relying on private contractors. The idea is to contract private companies to provide goods and services that are less expensive for the government to purchase than to provide for itself. Outsourcing and privatization are different methods to achieve the same goal, but the terms are often confused or the differences disregarded [Struble, 1996]. Table 1 contrasts the two methods.

	Outsourcing	**Privatization**
Ownership of Facilities	Government	Private Industry
Provides Workforce	Private Industry	Private Industry
Monitors Quality of Output	Government	Government

Table 1. Outsourcing and privatization are two methods to reduce operating costs. Outsourcing "contracts out" just the labor force, whereas privatization relinquishes complete control of the supply of a good or service to private providers.

Outsourcing refers to the purchase of inputs by the government from private providers. In this case, functions that are traditionally done in-house are shifted to the private sector. The workload shifts, but no government facilities are transferred to private industry. The government retains ownership of the facilities and a significant amount of control over operations. Outsourcing is also referred to as "contracting out" [Tighe, et al., 1996]. Figure 3 displays facilities maintenance as an example of a function that may be outsourced [Struble, 1996].

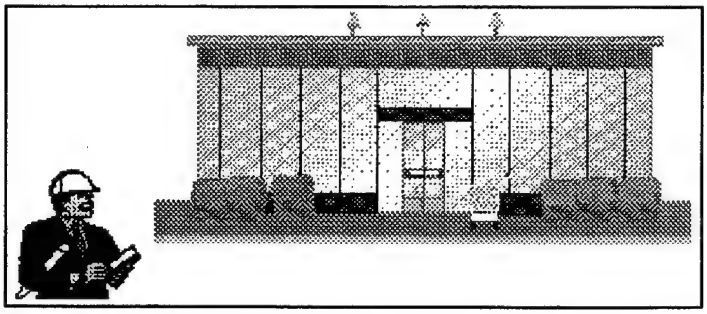

Figure 3. Outsourcing contracts the workforce from private providers. An example of outsourcing is when the government hires private companies to provide facilities maintenance.

Privatization, on the other hand, occurs when a governmental body relinquishes complete control of the supply of a good or service to private providers. "More specifically, it can be defined as shifting the production of government goods and services, or the ownership of assets, into the private sector" [Nuskey, 1992]. The government only monitors the quality of the output and has no involvement in the daily operations. For instance, if the Navy were no longer to provide child development centers (child care services) and relied solely upon private providers while monitoring their performance on a regular basis, then child care services would be privatized (Figure 4).

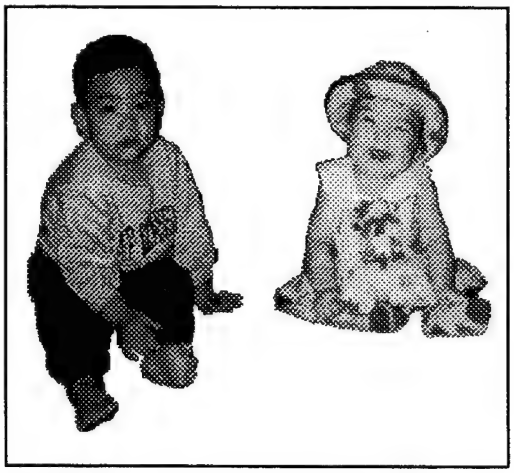

Figure 4. Privatization occurs when private providers have complete control of the government's supply of a good or service. Navy child care services, for example, may be privatized by relying solely upon private child care providers.
[Pictured: Charles and Jessica Kerman]

Outsourcing (henceforth used in its colloquial form to encompass both outsourcing and privatization) is by no means a new idea, and the private sector has used outsourcing as a means of cost reduction for many years. The Outsourcing Institute, for instance, was founded in 1993 as an internationally recognized private sector professional association for objective, independent information on the strategic use of outside resources. The Institute's headquarters is in New York City, and its members consist of executives and managers responsible for outsourcing as well as executives and managers providing such. According to the Institute:

> Outsourcing is rapidly becoming an accepted management tool for redefining and reenergizing the corporation. It challenges today's executive to rethink the traditional vertically-integrated firm in favor of a more flexible organization structured around core competencies and long-term outside relationships. [The Outsourcing Institute, 1997]

The federal government is now following private industry trends, and renewed emphasis has been placed on outsourcing. In the past, administrative and legislative constraints limited government outsourcing efforts. Continuing budgetary and personnel limitations, the need to fund weapons and modernization, and the elimination of key legislative constraints now allow the Department of Defense (DOD) to further outsource support functions. Outsourcing for commercial services is now a growing practice within the government to achieve cost savings, management efficiencies, and operating flexibility [United States General Accounting Office (GAO), 1997].

Results from the April 1996 Center for Naval Analyses (CNA) report [Tighe, et al., 1996] indicate that competition, not outsourcing, is the key to savings since winners of competitions usually use fewer workers. Thus, outsourcing induces savings, usually through personnel reductions, regardless of whether competitions are won by the government or the private sector. Furthermore, DOD data on cost comparisons for fiscal years 1978 through 1994 confirm that savings from competed functions follow regardless

of whether the government or private industry is awarded the work. According to the data, the government won half of the competitions and private industry won the other half [GAO, 1997].

The Defense Science Board Task Force on Outsourcing and Privatization [1996] concluded that the DOD could realize savings between 20 and 40 percent by outsourcing support functions; this translates to saving billions of dollars. Several other studies, including the April 1996 CNA report [Tighe, et al., 1996], support these figures.

Outsourcing has the endorsement of high level leadership, including the Secretary of the Navy (SECNAV), the Chief of Naval Operations (CNO), and the Commandant of the Marine Corps (CMC). In May of 1996, the CNO directed the DCNO for Logistics to establish a new division headed by a Navy Admiral to develop a Navy-wide competition and outsourcing strategy. This action was in direct support of guidance from SECNAV to "maximize outsourcing and privatization to the extent allowed under current law" [Office of the Chief of Naval Operations, 1996]. Hence, the Outsourcing Programs Division, or N47, was formed. N47 acts as the CNO's lead for outsourcing and privatization issues, providing liason with the Office of the Secretary of Defense, Office of Management and Budget, and Congress [N47, 1997].

3. Improved Operational Procedures

Improving operational procedures also reduces shore infrastructure. Better business practices include implementing commercial performance standards and measures, utilizing state-of-the-art technology, and reviewing military product specifications in order to use commercially available products to satisfy military requirements when applicable [N464, 1996a].

The specific better business practice of homebasing is mentioned in N47's charter. The idea behind homebasing is simple. Navy shore installations, by nature, have a certain number of personnel who rotate between sea and shore duty. This is called a "sea-shore rotation," and this process can be represented by a simple Markov chain as shown in Figure 5.

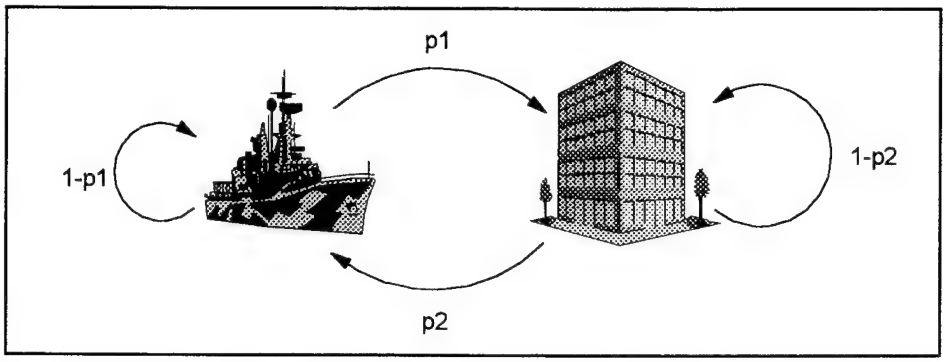

Figure 5. This simple Markov chain represents the sea-shore rotation at one Navy shore installation. p1 and p2 are the fractions of personnel per unit time rotating from sea to shore and shore to sea, respectively.

Frequently, when an individual rotates from sea to shore (or vice versa), he is not stationed at the same shore installation. In order to reduce costs, the Navy wants to maintain the majority of its personnel in one location or at one "home" base throughout these rotations. Such "homebasing" is illustrated in Figure 6. "The Navy initiative helps Sailors improve their quality of life by increasing geographic stability for them and their families, and it helps the Navy to reduce costs associated with Permanent Change of Station (PCS) moves" [Navy Wire Service, 1997].

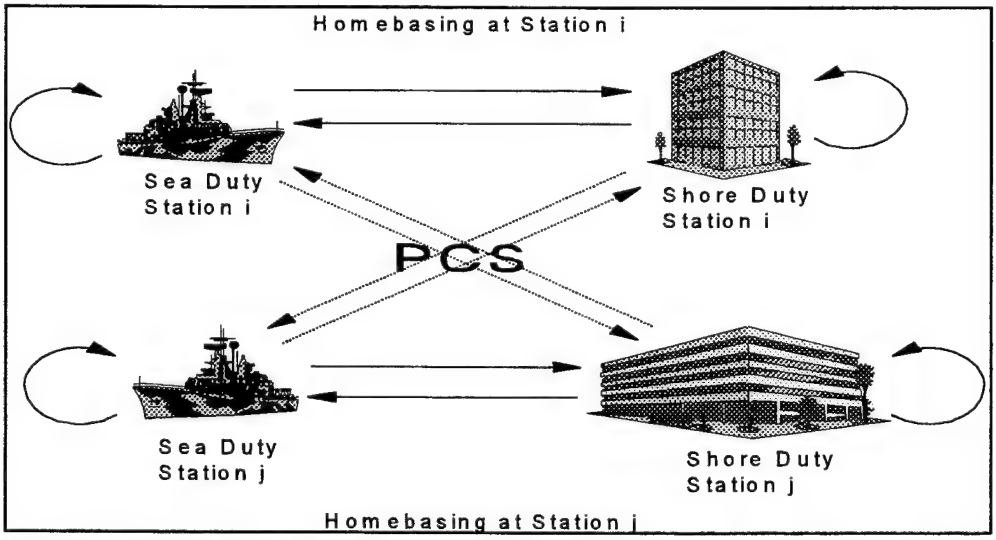

Figure 6. The goal of homebasing is to maintain personnel at the same station throughout their sea-shore rotations or limit transfer of personnel between stations i and j (along a dotted line). Personnel transfer or Permanent Change of Station (PCS) between shore locations is expensive.

C. THE NAVY PERSONNEL STRUCTURE

This section presents a brief introduction to the basic terminology and structure of the Navy's personnel system. The Plans and Policy Branch of SIMD gathers manpower data at each shore installation and bases all recommendations on this data.

The Navy's workforce consists of three basic types of personnel: officer, enlisted, and civilian. Navy officers are categorized by rank, designator, and sub-specialty codes. "Rank" refers to the salary level (or pay grade) of the officer and is usually commensurate with the amount of time that the officer has been in the service. There are ten Navy officer ranks, O-1 (Ensign) through O-10 (Admiral). A "designator" is a number that refers to the officer's occupational field. An 1120 (spoken "eleven-twenty") designator, for instance, indicates a submarine officer, and a 1700 (spoken "seventeen-hundred") designator indicates a fleet support officer. An officer may also have sub-specialty codes used to indicate special qualifications.

Enlisted personnel are categorized in the same manner as officers, but the terminology is different. The use of the word "rank" for Navy enlisted personnel is technically incorrect; the correct term is "rate." There are nine enlisted rates, E-1 (Seaman Recruit) through E-9 (Master Chief Petty Officer). Similarly, enlisted personnel have "ratings" rather than "designators." "A rating is a Navy job — a duty calling for certain skills and aptitudes" [United States Naval Institute, 1978]. The rating of radioman, for example, indicates a person instructed in the proper operation of radio communications systems. Finally, enlisted personnel have Navy Enlisted Classification (NEC) Codes rather than sub-specialty codes to indicate their aptitudes, special skills, and qualifications. Very senior enlisted personnel may be selected to become non-commissioned officers (NCO's). These personnel form the Chief Warrant Officer ranks, W-1 through W-5.

Civilian personnel also have a similar categorization. The civilian government service (GS) level is similar to the officer rank structure with levels GS-1 through GS-15. Senior civilian personnel may be selected for Senior Executive Service (SES). The civilian occupational field is called the "series," which is similar to officer designators.

D. PROBLEM DEFINITION

Regionalization, outsourcing, and homebasing all sound like effective, cost-saving initiatives. However, they must work together and still meet the Navy's personnel and job, or "billet," requirements. While regionalization and outsourcing reduce the number of billets needed at a shore installation, homebasing may increase the number of personnel available. These conflicting cost-saving initiatives require careful implementation.

Currently, N464 gathers manpower data and provides several regionalization options for each function on a Navy shore installation. Then, N47 considers regionalization, manpower, and homebasing when making outsourcing recommendations for the shore installations. This thesis addresses the issues concerning the regionalization and outsourcing of Navy shore installations and develops an integer linear programming model to assist both N464 and N47.

The Regionalization and Outsourcing Optimization Model (ROOM) identifies the optimal combination of regionalization and outsourcing options for a Navy shore installation. ROOM minimizes cost by selecting the best combination of regionalization and outsourcing options that can be supported by personnel available after homebasing adjustments.

E. THESIS OUTLINE

Chapter II describes some of the current Navy initiatives to further reduce infrastructure costs and addresses areas of related research. Chapter III introduces ROOM by providing an extensive discussion of its assumptions, data requirements, and features. Chapter IV presents ROOM's results for a data set from Pearl Harbor, Hawaii. Finally, Chapter V offers conclusions concerning the usefulness of ROOM, recommendations for future enhancements, and discusses areas for further study and research.

Appendix A lists all functions and associated function codes for the Pearl Harbor data. Appendix B contains ROOM's recommendations at the function level for four different test cases.

II. RELATED RESEARCH

A. ADDITIONAL NAVY INFRASTRUCTURE COST REDUCTION INITIATIVES

Homebasing, regionalization, and outsourcing and privatization are just a few of the recent Navy initiatives to reduce infrastructure costs. Additional initiatives under development that may enhance future ROOM use include: (1) the Smart Base project and (2) the Installation Information Transfer and Exchange (INSITE) system.

1. The Smart Base Project

The Smart Base project is aimed at streamlining Navy operations by improving shore installation management and reducing overhead. Its objective is to evaluate, select, and then implement advanced, commercially available technologies and management methods. Its goal is to exploit the use of commercial and governmental off-the-shelf technologies in order to improve the affordability of operations and reduce infrastructure costs. Smart Base is a focused and integrated effort to bring Navy shore installations to technological and efficiency levels available at commercial sites without sacrificing readiness or quality of installation management and services [N464, 1996a].

N466, the Information Infrastructure Branch of N46, is responsible for the Smart Base project. Core team members of the project represent a variety of activities and include personnel from the Office of the Chief of Naval Operations, Commander and Chief Atlantic Fleet, Office of Naval Research, Naval Facilities Engineering Command, Naval Sea Systems Command, Bureau of Naval Personnel, Naval Computer and Telecommunications Command, Naval Station Pascagoula, Bureau of Medicine and Surgery, Naval Supply Systems Command, Defense Logistics Agency, and Naval Surface Warfare Center. The host site for the project is the Naval Surface Warfare Center in Carderock, Maryland [Naval Surface Warfare Center, 1997].

The Smart Base program requires that all authorized personnel be issued a Multiple Technology Automated Reader Card (MARC). These cards can provide the gateway to the Smart Base facilities and services. Information contained on the MARC,

or "Smart Card," includes security, medical, personnel, financial, and other accesses tailored to the individual. As the card is used, it automatically updates databases, eliminating the need for laborious and time-consuming data entry. Travel is one example where significant savings in both time and cost can be realized. The support base necessary to service travelers will be significantly reduced because they will be able to check in or out of rooms without waiting in line or interfacing with a clerk. The Smart Card is simply placed in a kiosk-type device similar to a bank automated teller machine (ATM), and the computer assigns the person a room and encodes the entry access key on the Smart Card. Military travelers will also be able to obtain their tickets, forward security clearances, enter financial commitments, and register itineraries with a single use of the MARC [N466, 1996].

A sample MARC appears in Figure 7. The card contains a two or eight kilobyte (KB) computer chip, a three by nine bar code, and photographic identification on the front. The back of the card has a cardholder signature block and a three-strip magnetic stripe similar to that of a credit card. The eight kilobyte computer chip can support up to 28 different applications and has room for 330 data fields. The encoding system used on this computer chip is the same as that used on the employee identification cards of International Business Machines Corporation (IBM). The first track of the magnetic stripe contains information for a government American Express card, the second track contains a pointer to the cardholder's security clearance information in the DOD database, and the third track is the only re-writeable track. This track is used for BQ's and contains the encoding for "hotel keys" [N464, 1996a].

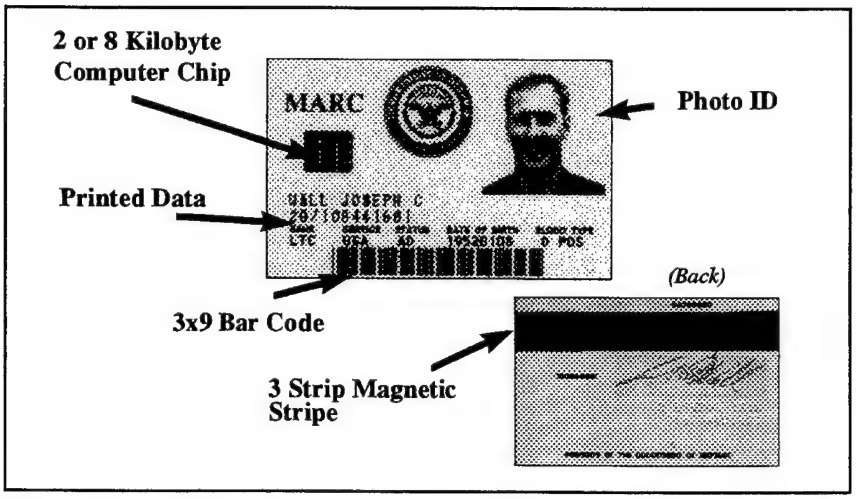

Figure 7. The Multiple Technology Automated Reader Card (MARC) provides the gateway to Smart Base facilities and services (not shown actual size). This "Smart Card" automatically updates databases as it is used, eliminating the need for laborious and time-consuming data entry.

MARC represents the future of the DOD's daily business routine. This technology will allow for tracking and reporting metrics at all levels.

2. Installation Information Transfer and Exchange (INSITE)

Installation Information Transfer and Exchange, or INSITE, is another decision support tool currently being implemented by the Navy. INSITE is a computer program that collects cost, quality, and quantity data from shore installation activities. The goal of INSITE is to give the Navy a higher return on its investment, promoting a higher quality of service, improving cost control, and driving informed decision making [N464, 1996a]. Again using BQ's as an example, the utility of BQ's is currently measured by the number of personnel staying each night. No cost or quality data is considered. INSITE expects to collect cost information for labor, purchased services, supplies, equipment, maintenance, utilities, communications, and other costs; quality data from customer satisfaction surveys, the facility condition index, staff training and testing, and quality self-assessments; and quantity data including the percent occupancy and the number of night stays for each BQ [N464, 1996a].

B. RELATED MODELS

This section examines a cross-section of the literature for models that share ROOM's goals or structure. Related models fall into two broad categories: Infrastructure cost reduction models and personnel assignment models.

1. Infrastructure Cost Reduction Models

Several models for military infrastructure reduction have been developed. The Cost of Base Realignment Actions (COBRA) [Brown, 1989] is an example. The Secretary of Defense's Commission on Base Realignment and Closure evaluated alternate proposals with both military effectiveness and economic feasibility as key criteria. COBRA is a cost model developed by the Logistics Management Institute and R & K Engineering to consider the economic feasibility criterion. The model estimates the cost of the major actions associated with the disposition of assets at closed bases and the transfer of activities to other bases. By providing this economic feasibility data, COBRA aided BRAC decision makers.

Along a similar vein, Dell, Fletcher, Parry, and Rosenthal [1994] develop the Optimally Stationing Units to Bases (OSUB) model. OSUB is an elastic bi-criterion mixed integer programming model that develops realignment and closure recommendations for maneuver and training bases by maximizing military value while minimizing operating cost. A large-scale example generated about 800 equations, 300 binary variables, 900 continuous variables, and 7,500 non-zeros. OSUB assisted the Army with stationing decisions during BRAC.

Free [1994] develops another BRAC-related optimization model. He presents a mixed integer linear program for scheduling Army base realignment and closure actions. The model generates an optimal schedule for the BRAC actions to achieve maximum savings within budget constraints. It was designed to assist The Army Basing Study (TABS), the primary analysis agency for developing 1995 Army BRAC recommendations. A test case using actual 1993 BRAC data generated a model with approximately 400 continuous variables, 70 binary variables, and 370 constraints. The model achieved a 34 percent increase in savings ($223 million) over the manual schedule developed by TABS

for this same data. Free's model evolved into the Base Realignment and Closure Action Scheduler (BRACAS) that was used to help determine implementation budgets for 1995 BRAC actions [Dell, 1997].

All of these models share ROOM's goal to decrease military infrastructure costs, but none of them provide regionalization and outsourcing recommendations for functions on a Navy installation.

2. Personnel Assignment Models

Several personnel assignment models have been developed to accommodate military requirements. Like ROOM, these models assign personnel to jobs at the minimum possible cost, and many have additional side constraints. Klingman and Phillips [1984] present one such personnel assignment model. They discuss the multicriteria problems faced by the United States Army, Navy, and Marine Corps in making enlisted personnel assignment decisions and present a new linear model and solution approach for the Marine Corps enlisted personnel assignment problem, the most complex of these problems. Computational results are shown for a problem with eleven criteria and approximately 10,000 constraints and 780,000 variables.

Gaimon and Thompson [1984] provide another variation of the personnel assignment model. They derive a cohort (longitudinal) personnel planning model solved using distributed parameter optimal control theory that requires cross-sectional data. The model considers personnel in cohort groups or groups that share the same organizational age. This model finds the optimal hiring, promotion, separation, and retirement policies of an organization as functions of time and an employee's organizational age and grade. The authors developed this model under contract with the Office of Naval Research, and they provide two small examples.

Navy personnel assignments are complicated by the fact that an individual can be sent to a technical school to obtain additional training, making him eligible for new jobs. Ali, Kennington, and Liang [1993] address the issue of billet assignment with en route training of Navy personnel. They develop a new algorithm based on resource-directive decomposition in conjunction with Lagrangean relaxation to solve the integer network

problem. The algorithm was tested with data obtained from the Navy Personnel Research and Development Center. The largest test case contained approximately 200 personnel, 100 jobs, and 40 schools, yielding about 4,000 arcs.

Blanco and Hillery [1994] describe the problems encountered in developing a personnel assignment model to assist the United States Navy. They discuss the negative impact of the personnel assignment model on an important detailing function: bargaining and assignment negotiations between the detailers (personnel assignment officers) and their customers, the service members. By involving the detailers in model revision, a failed program was turned into a successful model. Although this article does not present an actual model, the authors convey deep insight into modeling problems and compare their lessons learned with the experiences of other implementers. All modelers should be concerned with satisfying their customers, and this article is an excellent reference to avoid potential pitfalls.

There are numerous non-military related models and decision support systems for personnel assignment. Constantopoulos [1989], for example, presents the design of a large corporate decision support system for assigning large numbers of personnel to jobs according to multiple criteria. The system is composed of three modules: utility assessment, ordinary assignment, and special assignment. The utility assessment module determines the feasible assignments and develops a utility index for each one. The ordinary assignment module finds optimal assignments when there are no special conditions. Finally, the special assignment module handles all exceptional cases and provides a means to override the ordinary assignment procedure. The author develops his system design, but does not present any test cases.

Feiring [1993] describes another non-military personnel assignment model. His model assigns individuals to jobs by generating model values that reflect management's job assignment policy. The probability of an individual's success in a particular job is analyzed according to a general risk-assessment procedure. The author develops several integer linear risk-assessment models, but does not provide test cases or computational results.

C. MODEL DEVELOPMENT

As part of an unfunded research effort, Naval Postgraduate School professors Gerald Brown and Robert Dell proposed a model, entitled "Planning Optimal Use of Fleet Shore Support Infrastructure," as a tool to support the Fleet Shore Support and Installation Management Vision Working Group created by N46 [Brown and Dell, 1996]. This integer linear programming model minimizes total costs subject to personnel availability and substitutability, facility availability, and budget limitations. Total costs include operating costs, personnel costs, and facility costs. The personnel costs consider the costs to add, retrain, and eliminate both military and civilian personnel. Similarly, the facility costs include the funding necessary to add, eliminate, and convert facilities. Although this model provides a deep insight into the outsourcing problem, it requires a significant amount of cost data.

N464 obtained regionalization data from the San Diego Naval facilities in April, 1996. A simplification of the forementioned model was then designed by Professor Brown, Professor Dell, and Lieutenant Commander Toni Kasprzak to work with the San Diego data set [Brown, Dell, and Kasprzak, 1996]. The new model, entitled Optimal Shore Support Infrastructure (OSSI), is capable of evaluating opportunities for function outsourcing. The San Diego data set, however, contains no outsourcing information.

ROOM is the most recent revision of the OSSI model. It is designed to work with the Pearl Harbor data set and future data sets collected by N464.

III. REGIONALIZATION AND OUTSOURCING OPTIMIZATION MODEL

N464 collects data from an installation for regionalization studies and groups this data by function according to its Installation Management Function Code (IMFC). IMFCs are the creation of N464 and are meaningless to other departments of the Navy. Each Navy installation has a specific number of billets for each IMFC and a group of personnel available to fill these billets. Regionalization, outsourcing, and homebasing affect the number of personnel and billets available at an installation. The Regionalization and Outsourcing Optimization Model (ROOM) has been developed to assess the combined effects of these initiatives and assist N464 and N47 in making regionalization and outsourcing recommendations.

A. INTRODUCTION TO THE MODEL

ROOM is an integer linear program. It relies on the data collected by N464 for regionalization studies, limiting the amount of additional data necessary to execute the model. ROOM minimizes cost by selecting the best combination of regionalization and outsourcing options that can be supported by personnel available after homebasing adjustments.

B. MODEL ASSUMPTIONS

ROOM makes several simplifying assumptions:

1. The cost to perform a function using a specific regionalization and outsourcing option can be estimated by the personnel costs for the function and option combination. Other costs could easily be included in this estimated cost but are not currently available.

2. Personnel can be substituted into billets according to a set of allowable substitutions for personnel designator and rank combinations. These substitutions have associated training costs.

3. Function Activity Code General (FACG) billets are billets into which certain designator and rank combinations may be substituted with no associated training cost. Furthermore, there is a specific number of FACG billets available for each designator and rank combination.

4. There is a pool of personnel of each designator and rank combination available outside the installation and a demand for personnel moving out of the installation.

5. The cost to move military personnel to or from the installation is based upon the maximum permanent change of station (PCS) shipping weight allowances for personnel of the specific rank and the average cost per hundred pounds of goods shipped to or from the installation. Costs to move civilian personnel are not considered.

6. Monthly salaries for military personnel are based upon the average salary for the specific rank and include benefits, such as Variable Housing Allowances (VHA) and Cost of Living Allowances (COLA). Monthly salaries for civilian personnel are based upon the average salary for the specific GS level.

7. Monthly pay for part-time workers is estimated as 50 percent of the monthly salaries of their full-time counterparts. The part-time workforce can be grouped into one civilian GS level and series with a monthly salary equivalent to the average monthly pay of all part-time workers in the data set.

8. The contracted or outsourced labor cost for a specific function and option combination can be derived from the current outsourced labor cost and the additional number of personnel outsourced.

9. ROOM allows personnel additions, removals, and substitutions to be fractional.

10. The number of available personnel for each designator and rank combination is non-negative after adjusting for homebasing. ROOM, therefore, does not consider homebasing initiatives that would result in eliminating more billets of a designator and rank combination than currently available at an installation.

11. Billet reductions do not exceed the number of available billets for each function, designator, and rank combination.

C. ESSENTIAL ELEMENTS OF THE MODEL

1. Indices

- **d, d′** Civilian series, enlisted rating, or officer designator;
- **f** Installation Management Function Code (IMFC);
- **o** Regionalization and outsourcing option; and
- **r, r′** Civilian GS level, enlisted rate, or officer rank.

2. Data

a. Input

- $\mathbf{ALLOW_{dr}}$ Set of all designator d′, rank r′ allowed to substitute for designator d, rank r;
- $\mathbf{ALLOWF_{dr}}$ Set of all designator d′, rank r′ allowed to substitute for designator d, rank r as a FACG substitution;
- $\mathbf{FACG_{dr}}$ Number of FACG billets for personnel of designator d and rank r [personnel type (d, r)];
- $\mathbf{HOMEBASE_{dr}}$ Number of personnel type (d, r) eliminated or added by homebasing;
- $\mathbf{MOVEIN_{r}}$ Cost to move personnel of rank r to the installation;
- $\mathbf{MOVEOUT_{r}}$ Cost to move personnel of rank r from the installation;
- $\mathbf{MSAL_{r}}$ Monthly salary for personnel of rank r (base pay only);
- $\mathbf{OUTCOST_{fo}}$ Yearly contracted or outsourced labor cost for function f using option o;
- $\mathbf{PERS_{fdr}}$ Number of personnel type (d, r) in function f;
- $\mathbf{REDUCE_{fdro}}$ Billet reductions for personnel type (d, r) in function f under option o; and

- **$TRAIN_{d'dr'r}$** Training cost for designator and rank substitutions of designator d′, rank r′ for designator d, rank r.

b. Derived

- **$PAVAIL_{dr}$** Personnel of type (d, r) available
  $PAVAIL_{dr} = MAX(0, \sum_f PERS_{fdr} + HOMEBASE_{dr}) \quad \forall$ d, r;

- **$PNEED_{fdro}$** Personnel of type (d, r) needed in function f using option o
  $PNEED_{fdro} = PERS_{fdr} - REDUCE_{fdro} \quad \forall$ f, d, r, o;

- **$YSAL_r$** Yearly salary for personnel of rank r (base pay only)
  $YSAL_r = 12 \cdot MSAL_r \quad \forall$ r; and

- **$COSTTODO_{fo}$** Cost to perform function f using option o
  $COSTTODO_{fo} = \sum_{d,\,r} (PNEED_{fdro} \cdot YSAL_r) + OUTCOST_{fo} \quad \forall$ f, o.

3. Decision Variables

a. Binary

- **$perform_{fo}$** Equals one if function f is performed using option o. The value is zero otherwise.

b. Continuous

- **$facgsub_{d'dr'r}$** FACG substitutions from designator d′, rank r′ into designator d, rank r;

- **$pmovein_{dr}$** Number of personnel type (d, r) to move to the installation from other locations;

- **$pmoveout_{dr}$** Number of personnel type (d, r) to move from the installation to other locations; and

- **$sub_{d'dr'r}$** Non-FACG substitutions from designator d′, rank r′ into designator d, rank r.

4. Formulation

MINIMIZE Total Cost

$$\sum_{f,\,o} (\text{COSTTODO}_{fo} \cdot \text{perform}_{fo}) \quad +$$

$$\sum_{d,\,r} [\text{MOVEIN}_{r} \cdot \text{pmovein}_{dr} + \text{MOVEOUT}_{r} \cdot \text{pmoveout}_{dr}] \quad +$$

$$\sum_{d,\,r} \sum_{d',\ r' \in \text{ALLOWF}dr} (\text{YSAL}_{r'} - \text{YSAL}_{r}) \cdot \text{facgsub}_{d'dr'r} \quad +$$

$$\sum_{d,\,r} \sum_{d',\ r' \in \text{ALLOW}dr} (\text{YSAL}_{r'} - \text{YSAL}_{r} + \text{TRAIN}_{d'dr'r}) \cdot \text{sub}_{d'dr'r}$$

SUBJECT TO CONSTRAINTS:

$$\sum_{f,\,o} (\text{PNEED}_{fdro} \cdot \text{perform}_{fo}) = \text{PAVAIL}_{dr} + \text{pmovein}_{dr} - \text{pmoveout}_{dr} + \sum_{d',\,r' \in \text{ALLOWF}dr} \text{facgsub}_{d'dr'r} - \sum_{d',\,r':\,d,\,r \in \text{ALLOWF}d'r'} \text{facgsub}_{dd'rr'} + \sum_{d',\,r' \in \text{ALLOW}dr} \text{sub}_{d'dr'r} - \sum_{d',\,r':\,d,\,r \in \text{ALLOW}d'r'} \text{sub}_{dd'rr'} \qquad \forall\, d, r \qquad (1)$$

$$\sum_{o} \text{perform}_{fo} = 1 \qquad \forall\, f \qquad (2)$$

$$\sum_{d',\,r' \in \text{ALLOWF}dr} \text{facgsub}_{d'dr'r} \le \text{FACG}_{dr} \qquad \forall\, d, r \qquad (3)$$

$$\text{perform}_{fo} \in \{0, 1\} \qquad \forall\, f, o \qquad (4)$$

$$\text{pmovein}_{dr} \ge 0,\ \text{pmoveout}_{dr} \ge 0 \qquad \forall\, d, r$$
$$\text{facgsub}_{d'dr'r} \ge 0,\ \text{sub}_{d'dr'r} \ge 0 \qquad \forall\, d', d, r', r \qquad (5)$$

D. EXPLANATION

The objective function minimizes the total expense of meeting the billet and personnel requirements based solely upon personnel costs. The first summation represents the cost to perform all functions. The second summation represents the costs incurred due to moving personnel into or out of the installation. The third summation is the cost or savings due to FACG personnel designator and rank substitutions. The final summation is the cost or savings due to non-FACG personnel substitutions plus the associated personnel training costs.

Constraint set (1) balances billets and personnel. This constraint set guarantees that all billets are filled by personnel of the appropriate designator and rank combination or

an allowable substitute. Constraint set (2) ensures that only one option is chosen for each function. Constraint set (3) guarantees that the number of FACG substitutions does not exceed the number of FACG billets available for each personnel type. Constraint sets (4) and (5) specify variables as binary and non-negative, respectively.

IV. COMPUTATIONAL EXPERIENCE

A. INTRODUCTION

This chapter demonstrates the capabilities of ROOM using several test cases derived from a Pearl Harbor data set collected by N464. Regionalization, outsourcing, and "no change" options are available for each function. When examining the functions individually (function by function), the best myopic option has the lowest possible cost. To demonstrate the advantage of using ROOM, the best myopic options for functions are compared to ROOM's recommendations. A sensitivity analysis of ROOM's recommendations is also performed by varying the training costs and number of allowed FACG substitutions. We also see whether ROOM recommends outsourcing functions normally prevented from being outsourced due to legislative constraints. Finally, ROOM's values for savings and total training costs are used in a net present value (NPV) analysis to extend the savings over several years.

B. MODEL STATISTICS

The model is expressed in the General Algebraic Modeling System (GAMS) [Brooke, Kendrick, and Meeraus, 1988], which generates it and solves it with the Optimization Subroutine Library (OSL) [e.g., Wilson and Rudin, 1992]. ROOM contains approximately 20,000 continuous variables, 300 binary variables, and 1,400 constraints. All excursions reached optimal solutions within one minute on a Pentium-100 based personal computer.

C. PEARL HARBOR DATA

This section shows all index sets and sample data for Pearl Harbor. The displayed data sets are slightly modified from the original Pearl Harbor data; they show only a subset of the available Installation Management Function Codes (IMFCs) and only one regionalization option. Additionally, this section uses only two personnel classification terms. The term "designator" is used to refer to civilian series, enlisted rating, or officer designator. Similarly, the term "rank" encompasses civilian level, enlisted rate, and officer rank.

1. Index Sets

Tables 22a, 22b, and 22c of Appendix A show all 109 functions and associated IMFCs for the Pearl Harbor data. "Summary functions" are the general function categories and descriptions formed from multiple IMFCs. Table 2 lists 36 summary functions and their associated IMFCs for the Pearl Harbor data set.

ROOM groups Navy personnel according to designator and rank combinations. Table 3 lists the 341 personnel designators, and Table 4 shows the 41 ranks in the Pearl Harbor data. To reduce the size of the data set, part-time civilian workers are all grouped into the part-time worker (PTW) designator and part-time government worker (PTGW) rank. Also, note that not all designator and rank combinations exist.

Function	IMFC
Facilities & Real Estate	
Property Management and Utilities	A1
Utilities Operations and Maintenance	A2
Family Housing	A3
Bachelor Quarters	A4
Environmental Services	A5
Base Operations	
Security	B1
Communications	B2
Command and Staff	B3
Administrative Support Functions	B4
Safety Services	B5
Emergency Services	B6
Port Operations	B7
Air Operations	B8
Weapons Handling Operations	B9
Logistics Support	
Procurement	C1
Passenger Transportation	C2
Freight Transportation	C3
Retail Supply Services	C4
Fuel Services	C5
Personnel & Professional Support	
Legal Services	D1
Public Affairs Support	D2
Military Personnel Services	D3
Civilian Personnel Management	D4
Resource Management	D5
Printing and Publications Services	D6
Data Processing and Audio Visual Services	D7
Services Provided to Individuals	
Food Services	E1
Laundry Services	E2
Educational Services	E3
Religious Programs	E4
Family Services	E5
Child Care Services	E6
Other Personal and Family Services	E7
Morale, Welfare and Recreation Services	E8
Training	
Training	F1
Non Installation Management	
Non-Installation Management Functions	G1

Table 2. Pearl Harbor summary functions and their associated Installation Management Function Codes (IMFCs). Appendix A lists all 109 functions.

Designators						
Officer						
5	6	7	54	55	56	1000
1050	1110	1117	1120	112O	1130	1140
1300	1320	1440	1610	1630	1650	1700
1800	2000	2100	2105	2200	2300	2340
2500	2505	3100	3104	4100	5100	6110
6120	6160	6180	6190	6230	6260	6390
6400	6410	6480	6490	6530	6550	7110
7130	7140	7160	7161	7180	7190	719O
7210	7410	7440	7480	7490	7520	7521
R0050	R0051	R0052	R0053	R0057	R0058	R0059
R0060						
Enlisted						
AB	AD	AE	AF	AM	AT	
AV	AZ	AME	AMH	CU	DK	EQ
FTB	EOD	IM	ML	MT	OTA	OTM
PM	WT	ABE	ABF	ABH	AC	AG
AK	AMS	AO	AS	AW	BM	BT
BU	CE	CM	CN	CTA	CTI	CTM
CTO	CTR	CTT	DC	DM	DN	DP
DS	DT	EA	EM	EN	EO	ET
EW	FC	FN	FR	FT	GM	GMG
GMM	GS	GSE	GSM	HM	HN	HT
IC	IS	JO	LI	LN	MA	MM
MN	MR	MS	MU	NC	OM	OS
PC	PH	PN	PO	PR	QM	RM
RP	SH	SK	SM	SN	ST	STG
STS	SW	TM	UT	YN		
Civilian						
18	19	20	25	28	80	81
83	85	86	101	102	132	180
181	185	186	187	188	189	193
201	203	204	205	212	221	230
233	235	260	301	302	303	304
305	310	312	318	322	326	328
332	334	335	341	342	343	344
361	376	390	391	392	394	399
401	403	414	480	501	503	505
510	525	540	544	560	561	601
602	610	640	662	665	670	675
679	690	699	801	802	803	804
808	809	810	819	830	840	850
854	855	856	895	896	905	950
986	998	1001	1035	1071	1082	1083
1084	1101	1102	1103	1104	1105	1106
1130C	1150	1152	1170	1171	1173	1175
1199	1306	1311	1320C	1370	1410	1411
1515	1550	1601	1640	1670	1701	1702
1710	1712	1750	1802	1811	1910	2001
2003	2005	2010	2030	2102	2130	2135
2150	2151	2161	2604	2805	4701	4749
5703	6502	6907	7404	9172	GS0303	GS0318
GS0525	GS0802	WG2810	WG5378	WG5407	0006C	PTW

Table 3. Personnel designators for the Pearl Harbor data set. The term "designator" is a naming simplification used to refer to civilian series, enlisted rating, and officer designator. For example, the "1700" officer designator denotes a fleet support officer.

Ranks									
Officer									
O1	O2	O3	O4	O5	O6	O7	O8	O9	O10
W1	W2	W3	W4	W5					
Enlisted									
E1	E2	E3	E4	E5	E6	E7	E8	E9	
Civilian									
GS01	GS02	GS03	GS04	GS05	GS06	GS07	GS08	GS09	GS10
GS11	GS12	GS13	GS14	GS15	SES	PTGW			

Table 4. Personnel ranks for the Pearl Harbor data set. The term "rank" is a naming simplification used to refer to civilian level, enlisted rate, and officer rank.

ROOM considers the options shown in Table 5 for the Pearl Harbor data. N464 has six different regionalization plans available for Pearl Harbor. For brevity, the data sets show only one regionalization option for each function. The only outsourcing option available allows the entire function to be outsourced. Not all options exist for each function.

Regionalization and Outsourcing Options	
Option	Description
OPT1	Regionalization Plan 1
OPT2	Regionalization Plan 2
OPT3	Regionalization Plan 3
OPT4	Regionalization Plan 4
OPT5	Regionalization Plan 5
OPT6	Regionalization Plan 6
OPT7	Outsource the function
OPT8	No change

Table 5. Available options for Pearl Harbor shore installation functions. There are six different regionalization options, but only one option to outsource. "OPT5," for instance, denotes N464's fifth regionalization plan which recommends just the administrative support functions for regionalization.

2. Data Sets

Table 6 lists the monthly salaries by personnel rank. Monthly salaries for military personnel are based upon the average salary by rank and include benefits, such as VHA and COLA. Monthly salaries for civilian personnel are based upon the average salary by GS level. Monthly pay for part-time government workers (PTGW) is estimated as 50 percent of the monthly salaries of their full-time counterparts.

Monthly salary			
Rank	Salary	Rank	Salary
E1	$2,152.93	O8	$9,239.52
E2	$2,287.43	O9	$9,732.62
E3	$2,483.42	O10	$10,754.68
E4	$2,757.23	GS01	$1,220.75
E5	$3,084.13	GS02	$1,357.00
E6	$3,455.26	GS03	$1,516.00
E7	$3,873.39	GS04	$1,702.17
E8	$4,398.90	GS05	$1,904.08
E9	$5,002.20	GS06	$2,122.58
W1	$3,916.40	GS07	$2,358.58
W2	$4,181.33	GS08	$2,612.25
W3	$4,673.60	GS09	$2,885.25
W4	$5,055.74	GS10	$3,176.75
W5	$6,236.23	GS11	$3,490.75
O1	$3,595.57	GS12	$4,184.00
O2	$4,276.27	GS13	$4,975.25
O3	$5,138.01	GS14	$5,879.00
O4	$5,704.85	GS15	$6,915.50
O5	$6,334.34	SES	$7,200.00
O6	$6,905.10	PTGW	$1,179.29
O7	$8,307.84		

Table 6. Monthly salaries by personnel rank.

The costs to move personnel to and from Pearl Harbor are shown in Tables 7 and 8, respectively. These costs are based upon the maximum PCS shipping weight allowances for personnel by rank and the average cost per hundred pounds of goods shipped to or from the installation. ROOM does not consider the costs to move civilian personnel.

Cost to move personnel to the installation	
Rank	Cost
E1	$4,730
E2	$4,730
E3	$4,730
E4	$7,568
E5	$8,514
E6	$10,406
E7	$11,825
E8	$12,771
E9	$13,717
W1	$11,352
W2	$12,771
W3	$13,717
W4	$16,082
W5	$16,555
O1	$11,352
O2	$12,771
O3	$13,717
O4	$16,082
O5	$16,555
O6	$17,028
O7	$17,028
O8	$17,028
O9	$17,028
O10	$17,028

Table 7. Cost to move personnel by rank to Pearl Harbor.

Cost to move personnel from the installation	
Rank	Cost
E1	$4,800
E2	$4,800
E3	$4,800
E4	$7,680
E5	$8,640
E6	$10,560
E7	$12,000
E8	$12,960
E9	$13,920
W1	$11,520
W2	$12,960
W3	$13,920
W4	$16,320
W5	$16,800
O1	$11,520
O2	$12,960
O3	$13,920
O4	$16,320
O5	$16,800
O6	$17,280
O7	$17,280
O8	$17,280
O9	$17,280
O10	$17,280

Table 8. Cost to move personnel by rank from Pearl Harbor.

In order to choose the best option for each function, ROOM requires the current contracted or outsourced labor cost for each function and option combination. Table 9 is a subset of the Pearl Harbor outsourced labor costs by function and option combination. All regionalization options and the "no change" option contain the current outsourced labor cost for the function. The outsourced labor cost for each function under the outsource option is computed by multiplying the average yearly personnel salary for the function by the additional number of personnel to be outsourced and then adding this result to the current outsourced labor cost. For example, the average yearly personnel

salary for function code "A3a" is $30,000 with a current outsourced labor cost of $0, indicating that no personnel are currently outsourced. The outsource option desires to outsource 13 people, yielding an additional cost of $390,000. This $390,000 is added to the current outsourced labor cost of $0, giving a total outsourced labor cost of $390,000 for this function and option combination.

Contracted or Outsourced Labor Cost		
IMFC	Regionalize/No Change	Outsource
A1a	$52,913,000	$72,623,000
A1b	$121,114,025	$132,364,025
A1c	$11,503,000	$12,883,000
A2a	$124,933,000	$134,503,000
A3a	$0	$390,000

Table 9. A subset of Pearl Harbor outsourced labor costs by function and option combination. All regionalization options and the "no change" option contain the current outsourced labor cost for the function. The outsourced labor cost for function code "A3a," for example, is $390,000 under the outsource option and $0 under both the regionalization and "no change" options.

Personnel and billet data compose the last of ROOM's requirements. Current personnel in Pearl Harbor comprise the current personnel complement. ROOM requires the number of personnel in the current personnel complement by function, designator, and rank combination. Table 10 shows a subset of Pearl Harbor's personnel complement.

Current Personnel Complement			
IMFC	Designator	Rank	Number of Personnel
A1a	BM	E5	1
A1a	BM	E6	1
A1a	BM	E7	1
A1a	BU	E3	1
A1a	BU	E4	3
A1a	BU	E5	8
A1a	BU	E6	6
A1a	BU	E7	2
A1a	CE	E3	1
A1a	CE	E4	1
A1a	CE	E5	2
A1a	CE	E6	3
A1a	CM	E4	1
A1a	CM	E6	2
A1a	CN	E3	1
A1a	EA	E5	1
A1a	EM	E5	1
A1a	EN	E5	1
A1a	EO	E5	2
A1a	EO	E6	2
A1a	SH	E4	1
A1a	SW	E5	1
A1a	UT	E4	1
A1a	UT	E5	3
A1a	UT	E6	2
A1a	UT	E7	1

Table 10. A subset of the Pearl Harbor personnel complement. The numbers of personnel of specific designator and rank combinations are listed by function. For example, function code "A1a" has one electrician of designator "EM" and rank "E5."

Homebasing affects the number of personnel available at a given installation. N12, the total force programming and manpower office for the Department of the Chief of Naval Operations, is the source of homebasing data and makes all homebasing adjustments following a 70 percent homebasing policy [Mara, 1996]. This means that 70 percent of the personnel should remain in the same location for their next assignment, whereas 30 percent of the personnel should move to another installation. Table 11 contains a subset of the personnel adjustments for specific designator and rank combinations due to a 70 percent homebasing policy in Pearl Harbor. A positive number indicates additional

personnel, and a negative number indicates a personnel reduction. ROOM allows personnel reductions for each designator and rank combination as long as they do not exceed the number of available personnel. If homebasing recommends reductions beyond the current level of a designator and rank combination, ROOM reduces the level to zero.

Homebasing Adjustment				
	Rank			
Designator	E3	E5	E7	E9
AB	0	0	0	-1
AD	4	23	19	5
AE	4	19	42	4
AF	0	0	0	-2
AM	0	0	1	3
AT	-3	29	8	13
AV	0	0	0	-1
AZ	-7	5	-1	1

Table 11. A subset of homebasing adjustments for personnel levels in Pearl Harbor. Positive numbers indicate additional personnel and negative numbers indicate personnel eliminations. Designator "AD," for instance, gains four aviation machinists of rank "E3" due to homebasing.

ROOM allows for personnel substitutions. Function Activity Code General (FACG) billets are billets into which certain designator and rank combinations may be substituted with no associated training cost. The FACG billet availability for certain designator and rank combinations is shown in Table 12.

Number of FACG billets available						
	Rank					
Designator	E3	E4	E5	E6	E7	E8
AD	0	0	0	0	1	0
AE	0	0	0	0	1	0
FTB	0	1	0	0	0	0
ABE	0	0	1	2	0	0
ABF	0	0	1	2	0	0
ABH	0	0	1	3	1	0
AK	0	0	0	0	1	0
AMS	0	0	1	1	0	0
AO	0	8	0	3	1	1
AW	0	0	1	0	0	0
BM	0	6	22	9	1	5
BT	0	2	0	1	1	0
BU	0	4	0	1	0	0

Table 12. A subset of the number of Function Activity Code General (FACG) billets available in Pearl Harbor for specific designator and rank combinations. FACG billets are billets into which certain designator and rank combinations may be substituted with no associated training cost. For example, designator "AD" has one FACG billet available for an aviation machinist of rank "E7."

Reductions also occur in the number of available billets due to regionalization and outsourcing. A modified subset of the billet reductions by function, designator, rank, and option combination appears in Table 13.

Billet Reductions for each option					
IMFC	Designator	Rank	Regionalize	Outsource	No Change
A1a	BM	E5	0	1	0
A1a	BM	E6	0	1	0
A1a	BM	E7	0	1	0
A1a	BU	E3	0	1	0
A1a	BU	E4	0	3	0
A1a	BU	E5	4	8	0
A1a	BU	E6	4	6	0
A1a	BU	E7	1	2	0
A1a	CE	E3	0	1	0
A1a	CE	E4	0	1	0
A1a	CE	E5	1	2	0
A1a	CE	E6	2	3	0
A1a	CM	E4	0	1	0
A1a	CM	E6	0	2	0
A1a	CN	E3	0	1	0
A1a	EA	E5	0	1	0
A1a	EM	E5	0	1	0
A1a	EN	E5	0	1	0
A1a	EO	E5	1	2	0
A1a	EO	E6	1	2	0
A1a	SH	E4	0	1	0
A1a	SW	E5	0	1	0
A1a	UT	E4	0	1	0
A1a	UT	E5	2	3	0
A1a	UT	E6	1	2	0
A1a	UT	E7	0	1	0

Table 13. A subset of Pearl Harbor billet reductions by function, designator, rank, and option combination. For instance, designator "EM" and rank "E5" has one electrician's mate billet reduction under the "outsource" option for function code "A1a." Regionalization option one is shown in this table; not shown are five other regionalization options and numerous IMFCs.

ROOM requires allowable designator and rank substitutions for both FACG and non-FACG billets and training costs for non-FACG billet substitutions. ROOM defines allowable substitutions and their costs according to the following rules:

1. Allow FACG substitutions between all enlisted designators for personnel of the same rank.

2. Allow enlisted personnel to substitute into a billet requiring a person of the next higher rank and the same designator for a training cost of $700.

3. Allow enlisted personnel to substitute into a billet requiring a person of the next lower rank and the same designator for a training cost of $400.

4. Allow enlisted personnel to substitute between designators as long as they remain within one of the designator sets shown below. For example, an "ET," or electronics technician, may be substituted for a "FT," or fire control technician. These sets are derived from *The Bluejackets' Manual* [United States Naval Institute, 1978] descriptions of the enlisted ratings and a reasonable approximation of the required duties of each rating in a shore billet. Personnel of the same rank may substitute between designators with an associated training cost of $500. Personnel of one rank lower than the required billet rank may substitute with a training cost of $1000, and personnel of one rank higher have an associated training cost of $700.

{AB, AS}
{ABE, ABF, ABH}
{AK, DK, MS, SH, SK}
{BM, SM}
{BT, EM, EN, GS, GSE, GSM, IC, MM}
{BU, CE, CM, EA, EO, SW, UT}
{CTA, CTI, CTM, CTO, CTR, CTT}
{DM, JO, LI, PH}
{DP, DS}
{ET, FT}
{EW, OTA, OTM, ST, STG, STS}
{GM, GMG, GMM, MN, TM}
{HT, IM, MR, OM}
{LN, NC, PN, PC, YN, RP}
{OS, QM}
{PR, AE, AT, AD, AO, AM, AME, AMH, AMS, AZ}

5. Allow officers to substitute into a billet requiring a person of the next higher rank and the same designator for a training cost of $2000.

6. Allow officers to substitute into a billet requiring a person of the next lower rank and the same designator for a training cost of $1000.

7. Allow any officer designator to fill a 1000 designator coded billet. The associated training costs are $125 for officers of the same rank as the billet requirement, $250 for officers of one rank lower than the requirement, and $150 for officers of one rank higher.

8. Allow any warfare designated officer to fill a 1050 designator coded billet. Warfare designators include 1110, 1117, 1120, 1130, and 1140. The associated training costs are $125 for officers of the same rank as the billet requirement, $250 for officers of one rank lower than the requirement, and $150 for officers of one rank higher.

9. Allow no civilian personnel substitutions.

The author decided upon these training costs. The logic behind the training cost scaling follows:

1. $2000 and $1000 are the training costs for officer cross-rank substitutions into billets requiring the next higher and the next lower rank, respectively. These costs are high since there is a high desirability to fill officer billets with personnel of the required rank.

2. $700 and $400 are the training costs for enlisted cross-rank substitutions into billets requiring the next higher and the next lower rank, respectively. These costs are lower than the costs for officer rank substitutions since it is preferred to fill enlisted billets before officer billets with personnel of a substitutable rank.

3. $500 is the training cost for enlisted cross-designator substitutions. We prefer to fill an enlisted billet with a person of the next higher rank rather than perform a cross-designator substitution. On the other hand, we prefer to perform a cross-designator substitution rather than fill an enlisted billet with a person of the next-lower rank.

4. $1000 and $700 are the training costs for enlisted cross-designator, cross-rank substitutions into billets requiring the next higher and the next lower rank, respectively. We prefer both enlisted cross-designator substitutions and enlisted cross-rank substitutions to enlisted cross-designator, cross-rank substitutions. An enlisted cross-designator, cross-rank substitution into a billet requiring a person of the next lower rank has the equivalent training cost of an enlisted cross-rank substitution into a billet requiring a person of the next higher rank.

5. $125 is the training cost for officer cross-designator substitutions into 1000 and 1050 designator coded billets. This cost is low since 1000 and 1050 designator coded billets generally do not require any special skills.

6. $250 and $150 are the training costs for officer cross-designator, cross-rank substitutions into 1000 and 1050 designator coded billets requiring the next higher and the next lower rank, respectively. We prefer officer cross-designator substitutions to officer cross-designator, cross-rank substitutions. Additionally, these costs are lower than officer cross-rank training costs since the rank requirements of these billets are not strict.

D. MODEL INSIGHTS

N464 considers a subset of the Pearl Harbor functions as eligible for outsourcing (hereafter called the "N464 subset"). Tables 23a and 23b and Tables 24a and 24b of Appendix B designate the 23 functions in the N464 subset with asterisks (*). We form four test cases by considering either the N464 subset or all functions eligible for outsourcing, and by solving either ROOM or its linear programming (LP) relaxation. ROOM recommends only one option for each function, but the LP relaxation can provide fractional recommendations. For example, the LP relaxation may recommend to outsource half of a function and leave the remaining half unchanged.

To demonstrate the advantage of using ROOM, we first find the best myopic option for each function; the best myopic option is just the option with the lowest cost. ROOM would make these same recommendations if it did not consider homebasing adjustments or allow personnel substitutions. Table 14 totals the number of functions myopically selected for each option and compares these results to ROOM's optimal recommendations for the cases where the N464 subset and all functions are eligible for outsourcing. This table shows a significant difference in the number of functions recommended. Clearly, not all of the lowest cost options can be supported under homebasing in both cases.

Functions eligible for outsourcing	N464 subset			All		
Recommendation	Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
ROOM total	21	14	74	13	59	37
Myopic total	106	0	3	55	47	7
Difference	85	14	71	42	12	30

Table 14. A comparison of the totals of the best myopic option for each function and ROOM recommendations. The best myopic option for an individual function has the lowest cost. There is a significant difference between the totals and not all of the lowest cost myopic options can be supported under homebasing, demonstrating the contribution of ROOM.

Tables 15 and 16 total the recommendations by summary functions for the four test cases. Out of all 109 functions in the Pearl Harbor data, ROOM recommends 21 for regionalization, 14 for outsourcing, and 74 to remain the same when the N464 subset is eligible for outsourcing. When all functions are eligible for outsourcing, ROOM recommends 13 for regionalization, 59 for outsourcing, and 37 to remain the same. In this case, eight functions previously recommended for regionalization and 37 functions previously recommended to remain the same are now recommended for outsourcing. Many of the facilities and real estate, base operations, and personnel and professional support functions shift. Due to the personnel availability and substitutability constraints, shifts in the opposite direction occur in family housing, freight transportation, printing and publications services, and other personal and family services summary functions.

Tables 23a and 23b of Appendix B tabulate ROOM recommendations at the function level. ROOM recommends 14 of the 23 functions in the N464 subset, or 61 percent, for outsourcing; three functions are regionalized; and six functions do not change.

ROOM allows personnel additions, removals, and substitutions to be fractional. However, all results for the Pearl Harbor data set yielded intrinsically integer values, but this is not guaranteed for all data sets.

ROOM recommends only one option for each function, but the LP relaxation of ROOM has the advantageous ability to give fractional recommendations. Table 16 demonstrates the effects of changing the binary decision variables to continuous. When the N464 subset is eligible for outsourcing, both ROOM and the LP relaxation of ROOM yield the same results and recommendations. With all functions eligible for outsourcing, however, four of the summary functions have non-integer totals, indicating split

recommendations for one or more functions in each summary function group. These summary functions include security, communications, public affairs support, and other personal and family services. Each of these summary functions contains one or more functions whose recommendation is split between outsourcing and remaining the same.

Functions eligible for outsourcing	N464 subset			All		
Function Description	Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Facilities & Real Estate						
Property Management and Utilities	1	2	0	1	2	0
Utilities Operations and Maintenance	0	1	1	0	1	1
Family Housing	0	2	0	0	1	1
Bachelor Quarters	0	0	4	0	2	2
Environmental Services	1	0	4	0	4	1
Base Operations						
Security	2	0	6	2	4	2
Communications	0	0	3	0	3	0
Command and Staff	0	0	3	0	3	0
Administrative Support Functions	2	0	1	2	1	0
Safety Services	2	0	1	0	3	0
Emergency Services	0	0	3	0	1	2
Port Operations	0	0	5	0	1	4
Air Operations	0	0	3	0	2	1
Weapons Handling Operations	0	0	3	0	2	1
Logistics Support						
Procurement	2	0	1	1	2	0
Passenger Transportation	2	1	1	2	1	1
Freight Transportation	0	1	3	0	0	4
Retail Supply Services	3	0	5	2	2	4
Fuel Services	0	0	3	0	0	3
Personnel & Professional Support						
Legal Services	0	0	5	0	4	1
Public Affairs Support	2	0	2	0	4	0
Military Personnel Services	0	0	4	0	4	0
Civilian Personnel Management	0	0	1	0	1	0
Resource Management	1	0	2	0	3	0
Printing and Publications Services	0	2	0	0	0	2
Data Processing and Audio Visual Services	0	3	0	0	3	0
Services Provided to Individuals						
Food Services	1	0	1	1	0	1
Laundry Services	0	0	1	0	1	0
Educational Services	0	0	1	0	0	1
Religious Programs	0	0	1	0	1	0
Family Services	0	0	1	0	1	0
Child Care Services	0	0	1	0	0	1
Other Personal and Family Services	0	2	0	0	1	1
Morale, Welfare, and Recreation Services	2	0	2	2	0	2
Training						
Training	0	0	1	0	1	0
Non Installation Management						
Non-Installation Management Functions	0	0	1	0	0	1
TOTALS	21	14	74	13	59	37

Table 15. ROOM recommendations for the Pearl Harbor Naval Installation by summary functions. In ROOM, the decision variables for the option recommendations are binary. The numbers in the table represent the total number of functions recommended for each option.

Functions eligible for outsourcing	N464 subset			All		
Function Description	Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Facilities & Real Estate						
Property Management and Utilities	1	2	0	1	2	0
Utilities Operations and Maintenance	0	1	1	0	1	1
Family Housing	0	2	0	0	1	1
Bachelor Quarters	0	0	4	0	2	2
Environmental Services	1	0	4	0	4	1
Base Operations						
Security	2	0	6	2	4.14	1.86
Communications	0	0	3	0	2.62	0.38
Command and Staff	0	0	3	0	3	0
Administrative Support Functions	2	0	1	2	1	0
Safety Services	2	0	1	0	3	0
Emergency Services	0	0	3	0	1	2
Port Operations	0	0	5	0	1	4
Air Operations	0	0	3	0	2	1
Weapons Handling Operations	0	0	3	0	2	1
Logistics Support						
Procurement	2	0	1	1	2	0
Passenger Transportation	2	1	1	2	1	1
Freight Transportation	0	1	3	0	1	3
Retail Supply Services	3	0	5	2	2	4
Fuel Services	0	0	3	0	1	2
Personnel & Professional Support						
Legal Services	0	0	5	0	4	1
Public Affairs Support	2	0	2	0	3.48	0.52
Military Personnel Services	0	0	4	0	4	0
Civilian Personnel Management	0	0	1	0	1	0
Resource Management	1	0	2	0	3	0
Printing and Publications Services	0	2	0	0	0	2
Data Processing and Audio Visual Services	0	3	0	0	3	0
Services Provided to Individuals						
Food Services	1	0	1	1	0	1
Laundry Services	0	0	1	0	1	0
Educational Services	0	0	1	0		1
Religious Programs	0	0	1	0	1	0
Family Services	0	0	1	0	1	0
Child Care Services	0	0	1	0	0	1
Other Personal and Family Services	0	2	0	0	1.80	0.20
Morale, Welfare, and Recreation Services	2	0	2	2	0	2
Training						
Training	0	0	1	0	1	0
Non Installation Management						
Non-Installation Management Functions	0	0	1	0	1	0
TOTALS	21	14	74	13	62.04	33.96

Table 16. ROOM linear programming relaxation recommendations for the Pearl Harbor Naval Installation by summary functions. The decision variables for the option recommendations are continuous in the linear programming relaxation of ROOM. The numbers in the table represent the total number of functions recommended for each option.

Tables 24a and 24b of Appendix B contain the LP relaxation recommendations at the function level. The numbers in these tables can be interpreted as the fractions of the functions to regionalize, outsource, and remain the same. For example, public affairs support has nothing (or 0.00) in the "Regionalize" column, 0.48 in the "Outsource"

column, and 0.52 in the "No Change" column. This means that the LP relaxation of ROOM recommends outsourcing 48 percent of public affairs support and leaving 52 percent the same. So, if public affairs support requires 15 personnel, the LP relaxation recommends outsourcing about seven people.

It is also worth noting that base security and firefighting functions are legislatively prevented from being outsourced. When all functions are eligible for outsourcing regardless of the legislative constraints, ROOM still does not recommend these functions for outsourcing. Several related functions, however, are recommended for outsourcing. These functions include law enforcement, security training, investigative operations, military working dog programs, and disaster preparedness programs.

ROOM quantifies the total costs and savings due to implementing the optimal combination of regionalization and outsouring options. In order to compute the amount of savings, ROOM first determines the original cost of meeting all billet requirements without regionalizing or outsourcing personnel. This original cost is just the sum of the yearly salaries of all personnel in the installation's current personnel complement. ROOM outputs an optimal cost which is the minimum total cost due to implementing the optimal combination of regionalization and outsourcing options. The one-year savings is just the optimal cost subtracted from the original cost. Comparisons of the total costs and one-year savings for the four test cases appear in Tables 17 and 18, respectively.

Comparison of Total Costs			
	Integer Linear Program	Linear Program	Difference in
Functions eligible for outsourcing	Binary Decision Variable	Continuous Decision Variable	Total Costs
N464 subset	$672,217,867.12	$672,217,867.12	$0.00
All	$652,600,932.28	$652,485,679.41	$115,252.87
Difference in Total Costs	$19,616,934.84	$19,732,187.71	

Table 17. A comparison of total costs for the four model test cases. With the N464 subset of functions eligible for outsourcing, there is no difference in total costs between ROOM and its LP relaxation. With all functions eligible for outsourcing, the difference in total costs is $115,252.87. The difference in total costs between having the N464 subset of functions and all functions eligible for outsourcing is about $19.6 million for ROOM and $19.7 million for the LP relaxation of ROOM.

Comparison of Total Savings			
	Integer Linear Program	Linear Program	Difference in
Functions eligible for outsourcing	Binary Decision Variable	Continuous Decision Variable	Total Savings
N464 subset	$9,533,932.88	$9,533,932.88	$0.00
All	$29,150,867.72	$29,266,120.59	$115,252.87
Difference in Total Savings	$19,616,934.84	$19,732,187.71	

Table 18. A comparison of total savings for the four model test cases. With the N464 subset of functions eligible for outsourcing, there is no difference in the total savings between ROOM and its LP relaxation. With all functions eligible for outsourcing, the difference in total savings is $115,252.87. The difference in total savings between having the N464 subset of functions and all functions eligible for outsourcing is about $19.6 million for ROOM and $19.7 million for the LP relaxation of ROOM.

E. SENSITIVITY ANALYSIS

A sensitivity analysis of ROOM is performed by varying the training costs and allowed FACG substitutions. Table 19 summarizes the results of varying the training costs when the N464 subset is eligible for outsourcing. The training costs are varied as a percentage of the absolute value of the difference between the salaries of the person required to fill the billet and the person substituted into the billet. Notice that the model recommendations change by only one function as the training cost fraction increases from 0.2 to 0.3. The function shifts from an outsourcing recommendation to a recommendation to remain the same. Also, note that the total training costs increase about a half million dollars for each 0.1 increase in the training cost fraction. This trend continues until the training cost fraction is above 0.5. At this point, ROOM is substituting less personnel of different ranks and assigning more personnel of the required rank. The total training costs decrease at the 0.7 training cost fraction, slightly increase at 0.8, and then continue on a downward trend after 0.8. Ultimately, ROOM recommendations to outsource or regionalize functions are rather insensitive to changes in the training costs when the N464 subset is eligible for outsourcing.

	N464 subset eligible for outsourcing						
Training Cost Fraction	Regionalize	Outsource	No Change	Original Cost	Optimal Cost	Total Training Cost	Savings
0.1	21	14	74	$681,751,800.00	$671,750,700.00	$537,668.22	$10,001,050.00
0.2	21	14	74	$681,751,800.00	$672,282,800.00	$1,055,617.30	$9,468,965.42
0.3	21	13	75	$681,751,800.00	$672,801,400.00	$1,548,127.66	$8,950,432.06
0.4	21	13	75	$681,751,800.00	$673,315,400.00	$2,025,467.14	$8,436,436.90
0.5	21	13	75	$681,751,800.00	$673,821,600.00	$2,530,014.60	$7,930,233.52
0.6	21	13	75	$681,751,800.00	$674,313,600.00	$2,853,925.06	$7,438,195.62
0.7	21	13	75	$681,751,800.00	$674,666,700.00	$1,755,622.18	$7,085,079.94
0.8	21	13	75	$681,751,800.00	$674,915,100.00	$1,818,548.74	$6,836,747.62
0.9	21	13	75	$681,751,800.00	$675,101,100.00	$1,259,571.49	$6,650,658.03
1	21	13	75	$681,751,800.00	$675,228,100.00	$1,234,575.36	$6,523,665.64

Table 19. ROOM recommendations under varying training costs when the N464 subset of functions is eligible for outsourcing. Training costs are varied from 10 to 100 percent of the absolute value of the difference between the salaries of the person required to fill the billet and the person substituted into the billet.

Table 20 summarizes the results of varying the training costs when all functions are eligible for outsourcing. Again, the training costs are varied as a percentage of the absolute value of the difference between the salaries of the person required to fill the billet and the person substituted into the billet. In this case, ROOM recommendations remain the same for training cost fractions between 0.4 and 0.9. The large change in ROOM recommendations occurs when the training cost fraction increases from 0.3 to 0.4. Four functions shift from recommendations to remain the same to outsourcing recommendations. Overall, only seven functions out of the 109, or approximately 6.4 percent, shift recommendations as the training cost fraction varies. Again, this indicates that ROOM recommendations to outsource or regionalize functions are rather insensitive to changes in the training costs when all functions are eligible for outsourcing. The trend in the total training costs is similar to the case where the N464 subset is eligible for outsourcing.

	All functions eligible for outsourcing						
Training Cost Fraction	Regionalize	Outsource	No Change	Original Cost	Optimal Cost	Total Training Cost	Savings
0.1	13	57	39	$681,751,800.00	$652,277,800.00	$307,246.99	$29,473,970.00
0.2	13	58	38	$681,751,800.00	$652,581,200.00	$592,582.82	$29,170,580.00
0.3	13	57	39	$681,751,800.00	$652,873,700.00	$872,460.72	$28,878,090.00
0.4	13	61	35	$681,751,800.00	$653,152,400.00	$1,092,006.62	$28,599,410.00
0.5	13	61	35	$681,751,800.00	$653,417,400.00	$1,242,463.44	$28,334,420.00
0.6	13	61	35	$681,751,800.00	$653,643,100.00	$1,052,725.82	$28,108,650.00
0.7	13	61	35	$681,751,800.00	$653,808,000.00	$1,068,057.98	$27,943,780.00
0.8	13	61	35	$681,751,800.00	$653,903,000.00	$454,449.50	$27,848,770.00
0.9	13	61	35	$681,751,800.00	$653,947,200.00	$288,319.39	$27,804,630.00
1	13	62	34	$681,751,800.00	$653,973,700.00	$243,577.92	$27,778,140.00

Table 20. ROOM recommendations under varying training costs when all functions are eligible for outsourcing. Training costs are varied from 10 to 100 percent of the absolute value of the difference between the salaries of the person required to fill the billet and the person substituted into the billet.

A sensitivity analysis is also performed by varying the number of allowed FACG substitutions over multiple model runs. The results of this analysis indicate that ROOM recommendations, optimal costs, total training costs, and total savings are completely insensitive to changes in the number of allowed FACG substitutions in the Pearl Harbor data.

A combined model that varies training costs and the number of allowed FACG substitutions simultaneously yields similar results. The optimal costs and recommendations vary slightly with changes in the training cost fractions but remain constant for changes in the number of allowed FACG substitutions.

F. EXTENDING THE MODEL RESULTS OVER SEVERAL YEARS

ROOM computes annualized values for the savings and total training costs. The total training costs only apply to the first year since we assume they are paid up-front when the individual substitutes into the billet. The savings are recurrent and may apply to several years beyond the first year. To ascertain the approximate amount of money that the Navy will save over several years, we apply a standard discount rate to the annual savings and use a net present value (NPV) analysis.

Three percent is the standard discount rate used for each year [Defense Technical Information Center, 1997]. The implementation of ROOM with the N464 subset eligible for outsourcing is the base case for this analysis. This case yields a savings of approximately $10.5 million and a total training cost of $990,650. So, the first-year savings is about $9.5 million. Table 21 shows the NPV analysis over three years. This

analysis assumes that personnel rotate jobs after three years which is reasonably accurate for Navy shore billets. The gross savings over three years is $30.5 million which corresponds to about $28.8 million in present dollars.

Year	Factor	Savings	Net Present Value
1	0.97087	$9,533,932.88	$9,256,245.51
2	0.94260	$10,524,582.88	$9,920,428.77
3	0.91514	$10,524,582.88	$9,631,484.24
TOTAL		$30,583,098.64	$28,808,158.52

Table 21. A net present value analysis of the savings from ROOM recommendations over three years. The gross savings over three years is about $30.5 million, or $28.8 million in present dollars at a three percent discount rate.

G. SUMMARY OF RESULTS

Results from the Pearl Harbor data set demonstrate the flexibility of ROOM. Results from ROOM and its LP relaxation are compared for different test cases to examine the effects of split recommendations. When the N464 subset is eligible for outsourcing, the results of both ROOM and its LP relaxation are the same; all values for the decision variables are binary in both implementations. When all functions are eligible for outsourcing, 45 functions not contained within the N464 subset shift to outsourcing recommendations. Furthermore, with all functions eligible for outsourcing and the decision variables changed from binary to continuous, four functions previously recommended for no changes have their recommendations split between outsourcing and remaining the same.

ROOM does not outsource functions that are legislatively constrained from such, even when these functions are made eligible for outsourcing. However, ROOM recommends outsourcing many related functions, such as law enforcement and security training.

Sensitivity analyses include varying the training costs and the number of allowed FACG substitutions. Results show that ROOM recommendations to outsource or regionalize functions are very insensitive to changes in the training costs and completely insensitive to changes in the number of allowed FACG substitutions.

With the N464 subset eligible for outsourcing, ROOM yields a first-year savings of $9.5 million. Assuming associated training costs only occur in the first year and savings occur over three years, the net present value of expected savings is $28.8 million.

V. CONCLUSIONS

A. POSSIBLE USES OF THE MODEL

While regionalization and outsourcing decrease the number of available billets on a shore installation, homebasing generally increases the number of available personnel requiring billets. These opposing effects require careful implementation. Disregarding combined effects and homebasing, the least cost option for Pearl Harbor is to regionalize 106 functions, outsource none, and keep three the same. ROOM's optimal solution, accounting for the combined effects and homebasing, recommends regionalizing only 21 functions and outsourcing 14 functions, giving a first-year savings of $9.5 million. Assuming associated training costs only occur in the first year and savings occur over three years, the net present value of expected savings is $28.8 million. These results show a qualitative departure from myopic planning.

ROOM not only recommends specific functions for regionalization and outsourcing, but may also be used to determine the types of functions that should be targeted for further cost analysis studies. ROOM is capable of answering many "what-if" scenarios as demonstrated by ROOM's recommendations when all functions were made eligible for outsourcing regardless of legislative constraints.

B. AREAS FOR FUTURE ENHANCEMENTS

The completion of the INSITE system will vastly increase the amount of cost analysis data available to the Navy. Similarly, this increases the amount of data available to ROOM. ROOM should be modified to include INSITE data for operating and facilities costs, similar to the "Planning Optimal Use of Fleet Shore Support Infrastructure" model [Brown and Dell, 1996]. The integration of INSITE data into ROOM will give more accurate results and provide a deeper insight into regionalization and outsourcing issues.

The current version of ROOM requires the user to manually generate the data sets. This may be done with a word processor or by exporting data from a spreadsheet to a text file. All of this manual data generation requires many hours of work. For this reason, it is recommended that future versions of ROOM incorporate a graphical user interface (GUI)

as a front-end to the model. This GUI should provide an interface to transfer INSITE data to ROOM and allow for easier data export from a spreadsheet. Additionally, the GUI could assist the user in checking the consistency between the data sets.

C. AREAS FOR FURTHER STUDY AND RESEARCH

Outsourcing has been successfully used in the corporate world for many years. The government and branches of the military are emphasizing regionalization and outsourcing to reduce costs. Several cost analysis studies indicate savings anywhere between 20 and 40 percent. More analysis is needed in this area to determine the exact amount of savings and the driving forces behind them.

APPENDIX A. INSTALLATION MANAGEMENT FUNCTION CODES

N464 collects data for each function on a Navy shore installation and groups this data according to its Installation Management Function Code (IMFC). Each function has a unique IMFC. IMFCs are the creation of N464 and have no meaning to other departments in the Navy. All 109 functions and their associated IMFCs for the Pearl Harbor data are shown in Tables 22a, 22b, and 22c.

Function	IMFC
Facilities & Real Estate	
Property Management and Utilities	A1
Maintenance/Repair of Real Property	A1a
Real Property Planning/Engineering Design	A1b
Facility Services	A1c
Utilities Operations and Maintenance	A2
Utilities	A2a
Energy Conservation	A2b
Family Housing	A3
Management and Administration of Family Housing including Off-Base Referrals	A3a
Maintenance and Repair of Family Housing	A3b
Bachelor Quarters	A4
Management and Administration of Family Housing	A4a
Front Desk Operations/Reservations	A4b
Janitorial and Maid Services	A4c
Maintenance and Repair of Facilities, and Equipment	A4d
Environmental Services	A5
Environmental Compliance	A5a
Hazardous Material Management and Operations	A5b
Hazardous Waste Management and Operations	A5c
Oil Spill Containment	A5d
Environmental Training	A5e
Environmental Protection	A5f
Base Operations	
Security	B1
Base/Facility Security	B1a
Law Enforcement	B1b
Security Training	B1c
Information/Personnel Security	B1d
Investigative Operations	B1e
Military Working Dogs Program	B1f
Brig, CCU, Deserter, Prisoner functions	B1g
PASS and Decal Services	B1h
Communications	B2
Telephone Management	B2a
Navy Message Operations	B2b
Command and Staff	B3
Shore Command and Executive Officer Functions and Immediate Staff	B3a
Command MasterChief Functions and Immediate Staff	B3b
Special Assistants (e.g. EEO, Command Eval, Internal Review)	B3c
Administrative Support Functions	B4
Command Administrative Functions (e.g. Admin Office)	B4a
Postal and Mail Operations	B4b
Safety Services	B5
Occupational Safety and Health Programs	B5a
Occupation Medical and Industrial Hygiene	B5b
Other Safety Programs (e.g. Traffic Safety)	B5c
Emergency Services	B6
Firefighting, Marshall, and Prevention Functions	B6a
Disaster Preparedness	B6b
Airfield Crash and Rescue Operations	B6c
Emergency Services Dispatch Operations and Alarm Monitoring and Maintenance	B6d

Table 22a. Pearl Harbor functions and Installation Management Function Codes (IMFCs). See also Tables 22b and 22c.

Function	IMFC
Port Operations	B7
Service and Utility Craft Operations and Maintenance	B7a
Pier Services	B7b
Tug and Harbor Pilot Operations	B7c
Degaussing and Deperming Operations	B7d
Other Miscellaneous Waterfront Operations	B7e
Air Operations	B8
Airfield operations including Air Traffic Control and Terminal Ops	B8a
Ground Electronics Maintenance and Support	B8b
All Other Miscellaneous Air Operations	B8c
Weapons Handling Operations	B9
Armory and Small Arms including Ranges	B9a
Conventional and Nuclear Weapons Handling Operations	B9b
Explosive Ordnance Disposal	B9c
Logistics Support	
Procurement	C1
Contract Pre-Award Functions	C1a
Contract Administration	C1b
Contract Technical Representative and Quality Assurance	C1c
Passenger Transportation	C2
Vehicle Operation and Management	C2a
Vehicle Maintenenace and Service	C2b
Mass Transit Functions	C2c
Freight Transportation	C3
Vehicle Operation and Management	C3a
Vehicle Maintenance and Service	C3b
Rail Transit Functions	C3c
Retail Supply Services	C4
Stock and Inventory Control Services	C4a
Receipt, Stowage, and Issue Functions	C4b
Supply Management and Administration Services	C4c
Supply Material Handling Services	C4d
Aviation Supply Support Services	C4e
SERVMART services	C4f
Outfitting services	C4g
Recruit Clothing Issue Services	C4h
Fleet Material Support Office services	C4i
Shop Store Services	C4j
Ships Parts Control Services	C4k
Material Transportation Office Services	C4l
Personal Property Office Services	C4m
Fuel Services	C5
Liquid Oxygen, O2 and N2 services	C5a
Petroleum products and services	C5b
Other Petroleum Products and Services	C5c

Table 22b. Pearl Harbor functions and Installation Management Function Codes (IMFCs). See also Tables 22a and 22c.

Function	IMFC
Personnel & Professional Support	
Legal Services	D1
Staff Judge Advocate Functions	D1a
General Counsel (OGC) Functions	D1b
Naval Legal Services Functions	D1c
Courts Martial Services	D1d
Public Affairs Support	D2
Staff (Internal) Public Affairs	D2a
External Public Affairs	D2b
Protocol and Visitor Services	D2c
Military Personnel Services	D3
Military Personnel Administration Functions	D3a
Career Counseling Functions	D3b
Transient Personnel Administration	D3c
Retiree/Memorial Affairs	D3d
Civilian Personnel Management	D4
Resource Management	D5
Comptroller Services	D5a
Budget and Accounting Services	D5b
DBOF Financial Management and Administration	D5c
Printing and Publications Services	D6
Reprographic Services	D6a
Printing Services	D6b
Data Processing and Audio Visual Services	D7
Automatic Data Processing Services	D7a
ADP and Software Training	D7b
Audio/Visual Services	D7c
Services Provided to Individuals	
Food Services	E1
Enlisted Dining/Galley Services	E1a
MWR Food Services	E1b
Navy Exchange Food Services	E1c
Laundry Services	E2
Educational Services	E3
Religious Programs	E4
Family Services	E5
Family Service Centers	E5a
Foster Care Services	E5b
Child Care Services	E6
Child Development Centers	E6a
Family Child Care	E6b
Other Personal and Family Services	E7
Substance Abuse Counseling and Treatment	E7a
Community Outreach Programs	E7b
Other Personal and Family Services	E7c
Morale, Welfare and Recreation Services	E8
Youth Center Operations	E8a
Recreation Services	E8b
Library Services	E8c
Recylcling Operations	E8d
Training	
Training	F1
Non Installation Management	
Non-Installation Management Functions	G1

Table 22c. Pearl Harbor functions and Installation Management Function Codes (IMFCs). See also Tables 22a and 22b.

APPENDIX B. MODEL RESULTS

N464 considers a subset of the Pearl Harbor functions for outsourcing (hereafter called the "N464 subset"). Asterisks (*) designate the 23 functions contained within the N464 subset. This appendix displays the results of four test cases. Either the N464 subset or all functions are eligible for outsourcing. Furthermore, the decision variables may either be binary as in the Regionalization and Outsourcing Optimization Model (ROOM), or continuous as in the linear programming (LP) relaxation of ROOM. The LP relaxation of ROOM has the advantage of being able to recommend fractions of functions for different options, whereas ROOM must choose one specific option for each function.

Tables 23a and 23b display ROOM recommendations for the test cases with the base data set where the N464 subset is eligible for outsourcing and a modified data set where all functions are eligible for outsourcing. With the N464 subset eligible for outsourcing, ROOM recommends 14 of the 23 functions, or 61 percent, for outsourcing; six to remain the same; and three for regionalization. Out of all 109 functions, ROOM recommends 21 for regionalization, 14 for outsourcing, and 74 to remain the same. With all functions eligible for outsourcing, ROOM recommends 13 for regionalization, 59 for outsourcing, and 37 to remain the same. Eight functions previously recommended for regionalization and 37 functions previously recommended to remain the same shift to outsourcing recommendations. Many of the facilities and real estate, base operations, and personnel and professional support functions shift from the recommendation to remain the same to a recommendation for outsourcing. Shifts also occur in the opposite direction. Family housing maintenance, transit functions, reprographic and printing services, and substance abuse counseling and treatment shift from outsourcing recommendations to recommendations to remain the same. The shifts in this direction are due to the personnel availability and substitutability constraints.

Functions eligible for outsourcing		N464 subset			All		
Function		Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Facilities & Real Estate							
Maintenance/Repair of Real Property	*	1			1		
Real Property Planning/Engineering Design	*		1			1	
Facility Services	*		1			1	
Utilities	*			1			1
Energy Conservation	*		1			1	
Management and Administration of Family Housing including Off-Base Referrals	*		1			1	
Maintenance and Repair of Family Housing	*		1				1
Management and Administration of Family Housing				1		1	
Front Desk Operations/Reservations				1			1
Janitorial and Maid Services				1			1
Maintenance and Repair of Facilities, and Equipment				1		1	
Environmental Compliance		1				1	
Hazardous Material Management and Operations				1			1
Hazardous Waste Management and Operations				1		1	
Oil Spill Containment				1		1	
Environmental Training				1		1	
Base Operations							
Base/Facility Security		1			1		
Law Enforcement				1		1	
Security Training				1		1	
Information/Personnel Security				1			1
Investigative Operations				1		1	
Military Working Dogs Program				1		1	
Brig, CCU, Deserter, Prisoner functions		1			1		
PASS and Decal Services				1			1
Communications				1		1	
Telephone Management				1		1	
Navy Message Operations				1		1	
Shore Command and Executive Officer Functions and Immediate Staff				1		1	
Command MasterChief Functions and Immediate Staff				1		1	
Special Assistants (e.g. EEO, Command Eval, Internal Review)				1		1	
Administrative Support Functions				1		1	
Command Administrative Functions (e.g. Admin Office)		1			1		
Postal and Mail Operations		1			1		
Occupational Safety and Health Programs		1				1	
Occupation Medical and Industrial Hygiene		1				1	
Other Safety Programs (e.g. Traffic Safety)				1		1	
Firefighting, Marshall, and Prevention Functions				1			1
Disaster Preparedness				1		1	
Emergency Services Dispatch Operations and Alarm Monitoring and Maintenance				1			1
Service and Utility Craft Operations and Maintenance				1			1
Pier Services				1			1
Tug and Harbor Pilot Operations				1			1
Degaussing and Deperming Operations				1		1	
Other Miscellaneous Waterfront Operations				1			1
Airfield operations including Air Traffic Control and Terminal Ops				1		1	
Ground Electronics Maintenance and Support				1		1	
All Other Miscellaneous Air Operations				1			1
Armory and Small Arms including Ranges				1			1
Conventional and Nuclear Weapons Handling Operations				1		1	
Explosive Ordnance Disposal				1		1	
Subtotal		8	5	37	5	30	15

Table 23a. ROOM recommendations for the Pearl Harbor Naval Installation. See also Table 23b.

Functions eligible for outsourcing		N464 subset			All		
Function		Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Logistics Support							
Contract Pre-Award Functions		1			1		
Contract Administration		1				1	
Contract Technical Representative and Quality Assurance				1		1	
Vehicle Operation and Management	*	1			1		
Vehicle Maintenance and Service	*	1			1		
Mass Transit Functions	*			1		1	
Other Transit Functions	*		1				1
Vehicle Operation and Management	*			1			1
Vehicle Maintenance and Service	*			1			1
Rail Transit Functions	*			1			1
Other	*		1				1
Stock and Inventory Control Services		1				1	
Receipt, Stowage, and Issue Functions		1			1		
Supply Management and Administration Services		1			1		
Supply Material Handling Services				1		1	
Aviation Supply Support Services				1			1
SERVMART services				1			1
Outfitting services				1			1
Recruit Clothing Issue Services				1			1
Liquid Oxygen, O2 and N2 services				1			1
Petroleum products and services				1			1
Other Petroleum Products and Services				1			1
Personnel & Professional Support							
Legal Services				1		1	
Staff Judge Advocate Functions				1		1	
General Counsel (OGC) Functions				1		1	
Naval Legal Services Functions				1			1
Courts Martial Services				1		1	
Public Affairs Support				1		1	
Staff (Internal) Public Affairs		1				1	
External Public Affairs		1				1	
Protocol and Visitor Services				1		1	
Military Personnel Services				1		1	
Military Personnel Administration Functions				1		1	
Career Counseling Functions				1		1	
Transient Personnel Administration				1		1	
Civilian Personnel Management				1		1	
Comptroller Services				1		1	
Budget and Accounting Services		1				1	
DBOF Financial Management and Administration				1		1	
Reprographic Services	*		1				1
Printing Services	*		1				1
Automatic Data Processing Services	*		1			1	
ADP and Software Training	*		1			1	
Audio/Visual Services	*		1			1	
Services Provided to Individuals							
Enlisted Dining/Galley Services		1			1		
MWR Food Services				1			1
Laundry Services				1		1	
Educational Services				1			1
Religious Programs				1		1	
Family Service Centers				1		1	
Child Development Centers	*			1			1
Substance Abuse Counseling and Treatment	*		1				1
Other Personal and Family Services	*		1			1	
Youth Center Operations				1			1
Recreation Services		1			1		
Library Services		1			1		
Recycling Operations				1			1
Training							
Training				1		1	
Non-Installation Management							
Non-Installation Management Functions				1			1
Subtotal		13	9	37	8	29	22
TOTAL		21	14	74	13	59	37

Table 23b. ROOM recommendations for the Pearl Harbor Naval Installation. See also Table 23a.

Tables 24a and 24b contain the recommendations from the LP relaxation of ROOM executed on the Pearl Harbor data set. With the N464 subset eligible for outsourcing, both ROOM and its LP relaxation give the same results; all values for the decision variables are binary in both cases. With all functions eligible for outsourcing, however, four of the functions have their recommendations split between outsourcing and remaining the same. These functions include military working dog programs, Navy message operations, public affairs support, and substance abuse counseling and treatment programs. The numbers in these tables can be interpreted as the fractions of the functions to regionalize, outsource, and remain the same. For example, public affairs support has nothing (or 0.00) in the "Regionalize" column, 0.48 in the "Outsource" column, and 0.52 in the "No Change" column. This means that the LP relaxation of ROOM recommends outsourcing 48 percent of public affairs support and leaving 52 percent the same. If public affairs support requires 15 personnel, for instance, the LP relaxation recommends outsourcing about seven people.

Functions eligible for outsourcing		N464 subset			All		
Function		Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Facilities & Real Estate							
Maintenance/Repair of Real Property	*	1			1		
Real Property Planning/Engineering Design	*		1			1	
Facility Services	*		1			1	
Utilities	*			1			1
Energy Conservation	*		1			1	
Management and Administration of Family Housing including Off-Base Referrals	*		1			1	
Maintenance and Repair of Family Housing	*		1				1
Management and Administration of Family Housing				1		1	
Front Desk Operations/Reservations				1			1
Janitorial and Maid Services				1			1
Maintenance and Repair of Facilities, and Equipment				1		1	
Environmental Compliance		1				1	
Hazardous Material Management and Operations				1			1
Hazardous Waste Management and Operations				1		1	
Oil Spill Containment				1		1	
Environmental Training				1		1	
Base Operations							
Base/Facility Security		1			1		
Law Enforcement				1		1	
Security Training				1		1	
Information/Personnel Security				1		1	
Investigative Operations				1		1	
Military Working Dogs Program				1		0.14	0.86
Brig, CCU, Deserter, Prisoner functions		1			1		
PASS and Decal Services				1			1
Communications				1		1	
Telephone Management				1		1	
Navy Message Operations				1		0.62	0.38
Shore Command and Executive Officer Functions and Immediate Staff				1		1	
Command MasterChief Functions and Immediate Staff				1		1	
Special Assistants (e.g. EEO, Command Eval, Internal Review)				1		1	
Administrative Support Functions				1		1	
Command Administrative Functions (e.g. Admin Office)		1			1		
Postal and Mail Operations		1			1		
Occupational Safety and Health Programs		1				1	
Occupation Medical and Industrial Hygiene		1				1	
Other Safety Programs (e.g. Traffic Safety)				1		1	
Firefighting, Marshall, and Prevention Functions				1			1
Disaster Preparedness				1		1	
Emergency Services Dispatch Operations and Alarm Monitoring and Maintenance				1			1
Service and Utility Craft Operations and Maintenance				1			1
Pier Services				1			1
Tug and Harbor Pilot Operations				1			1
Degaussing and Deperming Operations				1		1	
Other Miscellaneous Waterfront Operations				1			1
Airfield operations including Air Traffic Control and Terminal Ops				1		1	
Ground Electronics Maintenance and Support				1		1	
All Other Miscellaneous Air Operations				1			1
Armory and Small Arms including Ranges				1			1
Conventional and Nuclear Weapons Handling Operations				1		1	
Explosive Ordnance Disposal				1		1	
Subtotal		8	5	37	5	29.76	15.24

Table 24a. ROOM linear programming relaxation recommendations for the Pearl Harbor Naval Installation. See also Table 24b.

Functions eligible for outsourcing		N464 subset			All		
Function		Regionalize	Outsource	No Change	Regionalize	Outsource	No Change
Logistics Support							
Contract Pre-Award Functions		1			1		
Contract Administration		1				1	
Contract Technical Representative and Quality Assurance				1		1	
Vehicle Operation and Management	*	1			1		
Vehicle Maintenance and Service	*	1			1		
Mass Transit Functions	*			1		1	
Other Transit Functions	*		1				1
Vehicle Operation and Management	*			1			1
Vehicle Maintenance and Service	*			1			1
Rail Transit Functions	*			1		1	
Other	*		1				1
Stock and Inventory Control Services		1				1	
Receipt, Stowage, and Issue Functions		1			1		
Supply Management and Administration Services		1			1		
Supply Material Handling Services				1		1	
Aviation Supply Support Services				1			1
SERVMART services				1			1
Outfitting services				1			1
Recruit Clothing Issue Services				1			1
Liquid Oxygen, O2 and N2 services				1			1
Petroleum products and services				1			1
Other Petroleum Products and Services				1		1	
Personnel & Professional Support							
Legal Services				1		1	
Staff Judge Advocate Functions				1		1	
General Counsel (OGC) Functions				1		1	
Naval Legal Services Functions				1			1
Courts Martial Services				1		1	
Public Affairs Support				1		0.48	0.52
Staff (Internal) Public Affairs		1				1	
External Public Affairs		1				1	
Protocol and Visitor Services				1		1	
Military Personnel Services				1		1	
Military Personnel Administration Functions				1		1	
Career Counseling Functions				1		1	
Transient Personnel Administration				1		1	
Civilian Personnel Management				1		1	
Comptroller Services				1		1	
Budget and Accounting Services		1				1	
DBOF Financial Management and Administration				1		1	
Reprographic Services	*		1				1
Printing Services	*		1				1
Automatic Data Processing Services	*		1			1	
ADP and Software Training	*		1			1	
Audio/Visual Services	*		1			1	
Services Provided to Individuals							
Enlisted Dining/Galley Services		1			1		
MWR Food Services				1			1
Laundry Services				1		1	
Educational Services				1			1
Religious Programs				1		1	
Family Service Centers				1		1	
Child Development Centers	*			1			1
Substance Abuse Counseling and Treatment	*		1			0.80	0.20
Other Personal and Family Services	*		1			1	
Youth Center Operations				1			1
Recreation Services		1			1		
Library Services		1			1		
Recycling Operations				1			1
Training							
Training				1		1	
Non-Installation Management							
Non-Installation Management Functions				1		1	
Subtotal		13	9	37	8	32.28	18.72
TOTAL		21	14	74	13	62.04	33.96

Table 24b. ROOM linear programming relaxation recommendations for the Pearl Harbor Naval Installation. See also Table 24a.

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